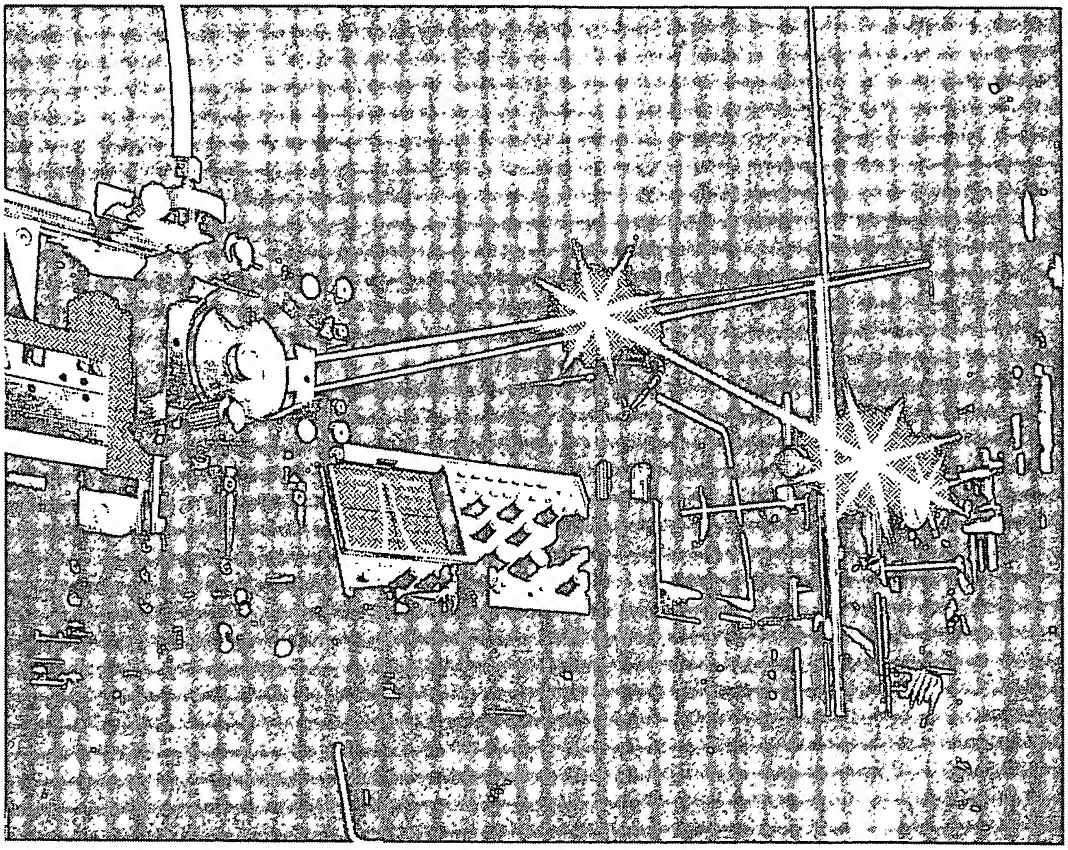
EXHIBIT A

GUIDE TO STREAK CAMERAS



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HAMAMATSU

Preface

This booklet has been put together in order to introduce the operating principle of streak cameras, show some examples of how streak cameras are used, offer guidelines on how to select a streak camera, and explain the terms used in connection with these instruments. We hope those who are interested in streak cameras and those who are considering buying a streak camera would find it useful. If you are looking for information on a specific product model, HAMAMATSU has individual catalogs available which describe the various models in greater detail. Please refer to those catalogs for the model in which you are interested.

Table of Contents

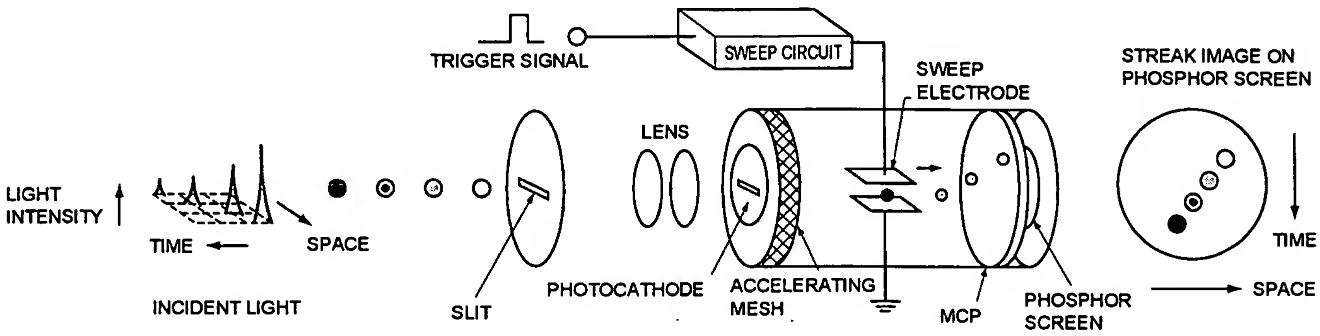


Fig.1 Operating Principle of the Streak Tube

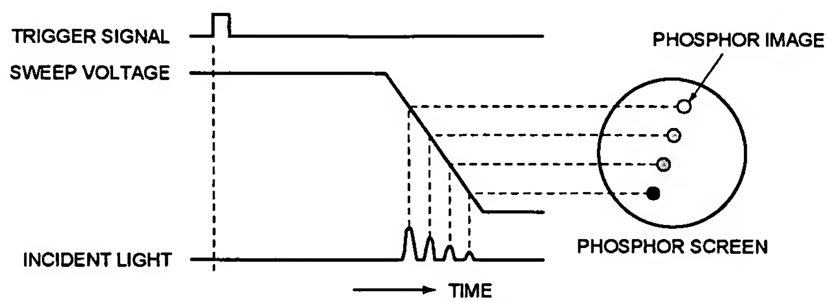


Fig. 2 Operation Timing (at time of sweep)

2 System Configuration

In order to measure ultra-high speed optical phenomena using a streak camera, a trigger section and a readout section are required. The basic configuration of this system is shown below.

The trigger section controls the timing of the streak sweep. This section has to be adjusted so that a streak sweep is initiated when the light being measured arrives at the streak camera. For this purpose, we use a delay unit, which controls how long the trigger signal which initiates the streak sweep is delayed, and a frequency divider, which divides the frequency of the external trigger signal if the repetition frequency of the trigger signal is too high. Also, in cases where the trigger signal cannot be produced from the devices such as a laser, it has to be produced from the light being measured itself, and this requires a PIN photodiode.

The readout section reads and analyzes streak images produced on the phosphor screen, which is on the output side of the streak camera. Because the streak image is faint and disappears in an instant, a high-sensitivity camera is used. Analysis of streak images is done by transferring the images through a frame grabber board to a computer.

In addition to the units which make up this basic configuration, there are spectroscopes, optics, and other peripheral equipments which can be used depending on each applications.

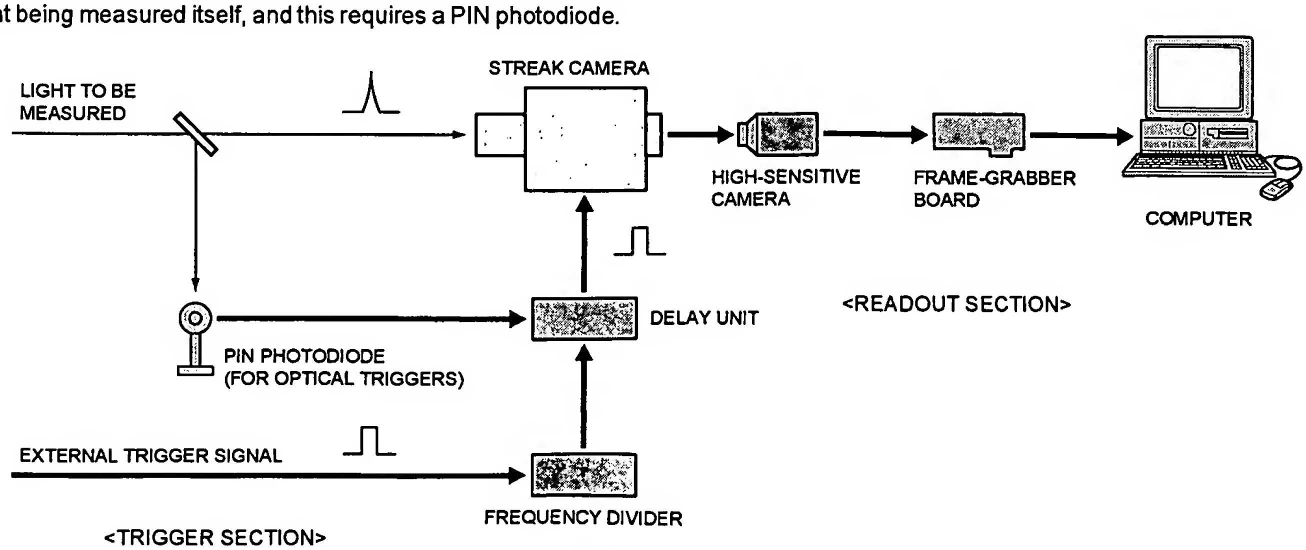
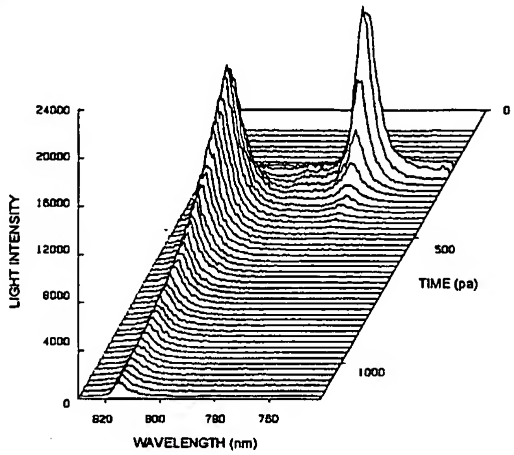
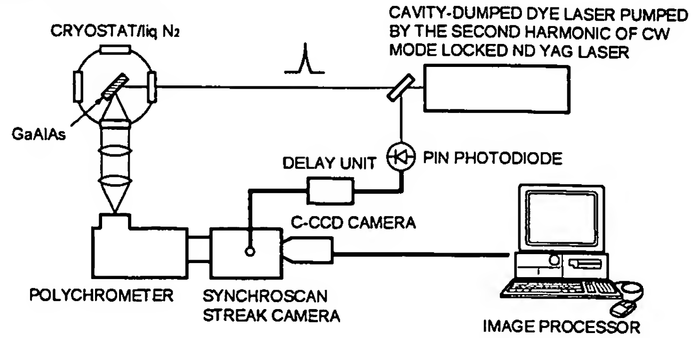


Fig. 3 Basic System Configuration of Streak Camera

3 Applications

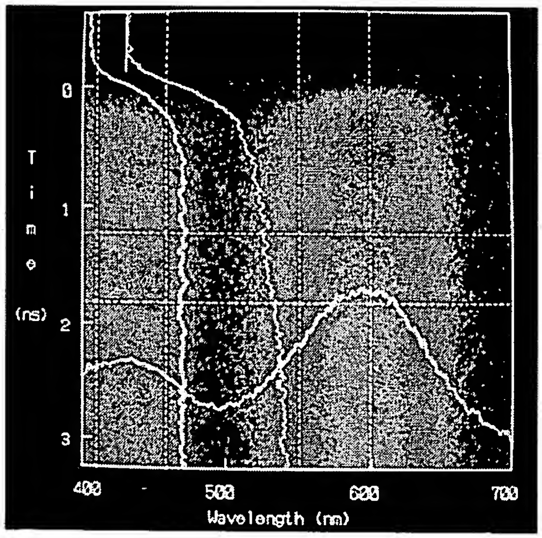
1 Semiconductor Physics (photoluminescence of GaAlAs)

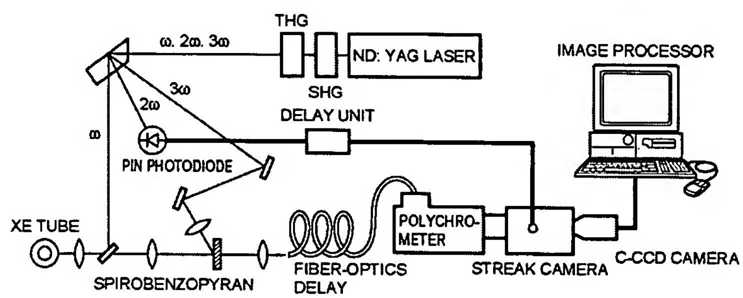




This is an example showing the photoluminescence of the compound semiconductor GaAlAs undergoing time-resolved spectroscopy.The specimen (GaAlAs) was excited using 580 nm picosecond pulses, and the photoluminescence emitted when electrons return to the ground state pass through a spectroscope where they undergo wavelength analysis. Following this, temporal resolution is carried out using a streak camera.

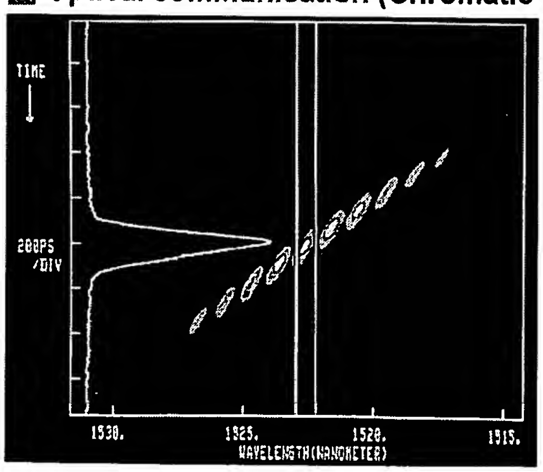
2 Photochemistry (Picosecond time-resolved absorption of photochromic compound)

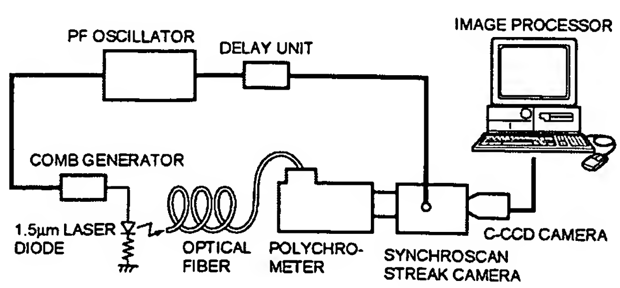




The absorbance change of spirobenzopyran in polystyrene film are measured by streak camera after the 355 nm excitation. The vertical curve shows the temporal changes in the degree of absorption in the first half of the 400 nm band and in the second half of the 500 nm band. The horizontal curve shows the absorption spectrum around 1.5 ns after excitation.

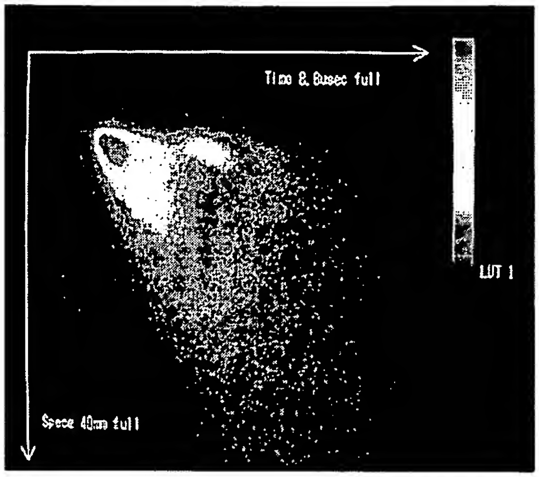
3 Optical communication (Chromatic dispersion in single mode optical fiber)



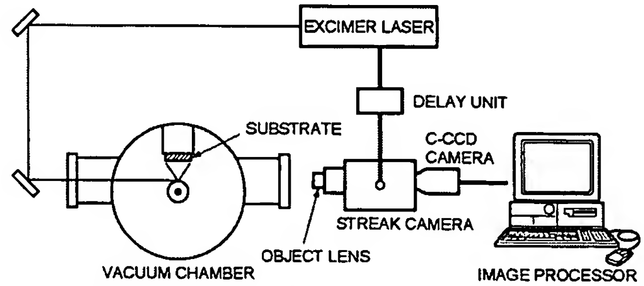


This is an example of a measurement of dispersion in time occurring in optical fiber. A laser diode with a wavelength of 1.5 μm generates many pluses having different wavelength at same timing, which are input to the optical fiber to be measured. The speed of the each optical pulses transmitting through the optical fiber varies depending on its wavelength. Thus, when the output light undergoes time-resolved spectroscopy after being transmitted a long distance, the differences of arrival time depending on each wavelength of a pulse can be measured.

4 Fabrication of high quality thin films (Laser ablation of YBCO)

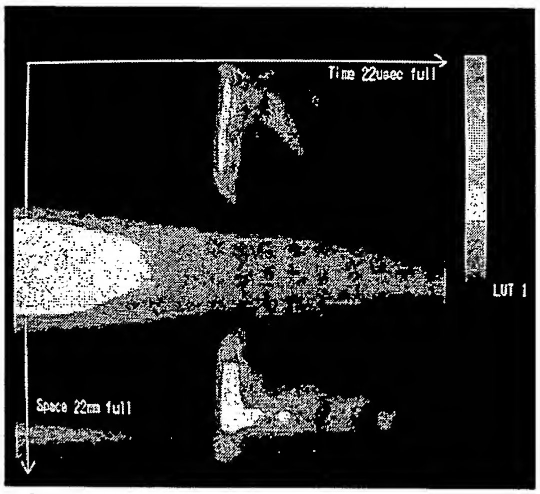


▲ Photo courtesy of Superconductivity Reserch Laboratory, ISTEC

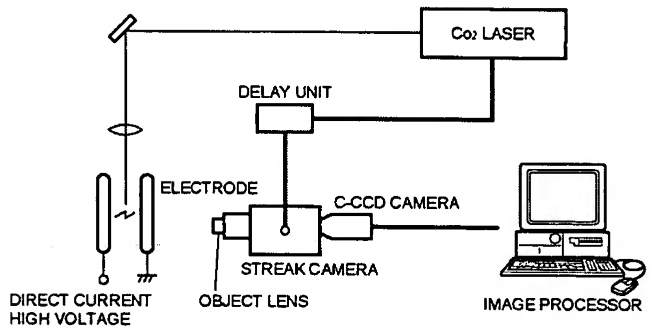


This example shows how, in order to create an oxide superconductivity thin film, the particles generated by a laser shot to a target scatter onto a substrate. We can see from the results that there are two components involved: one which arrives at the substrate at high speed, and a slower component which takes longer to reach the substrate.

5 Laser induced discharge

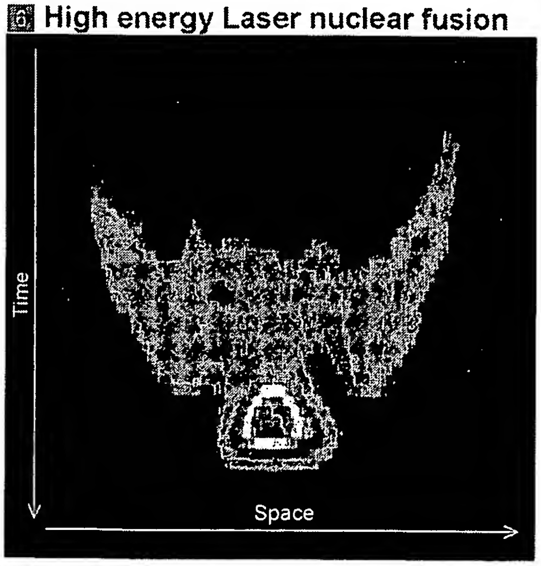


▲ Photo courtesy of Assistant Prof. Honda
Graduate School of Engineering Sciences, Kyushu University

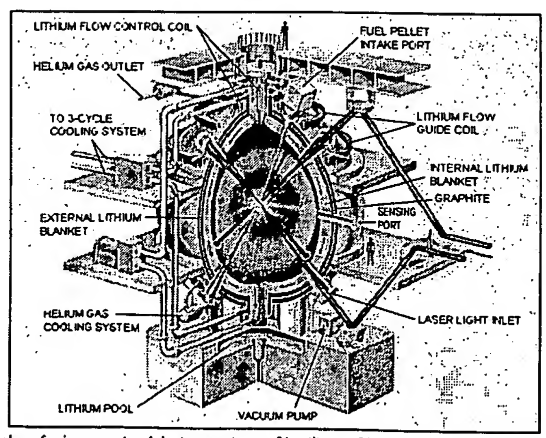


In this example, laser-induced discharge is measured. By focusing a strong pulsed beam between electrodes to which a direct-current high voltage has been applied, plasma is created, and this induces electrical discharge between the electrodes.

6 High energy Laser nuclear fusion



▲ Photo courtesy of Institute of Laser Engineering, Osaka University



▲ Laser nuclear fusion reactor (photo courtesy of Institute of Laser Engineering, Osaka University)

When a light element initiates nuclear fusion and changes to a heavy element, explosive energy is given off which is nothing like the chemical energy seen in combustion and other forms. Measurement of the intensity and the response time of light produced through the explosive flux-compression which takes place in the nuclear fusion reactor takes place here, along with measurement of the density and distribution of plasma ions and other factors.

4 Selection Guide

This table summarizes the main features and specifications of typical streak cameras manufactured by HAMAMATSU. We hope this will serve as a reference in selecting the optimum model for your applications.

Model No.	Features	Spectral Response Characteristics	Sweep Unit (Plug-in type)	Daynamic Range (at the fastest range) See Page 10
C6860 (Synchroscan Fesca)	The newly developed Synchroscan FESCA achieves an ultra-high temporal resolution at a high repetition frequency of 75 to 100 MHz synchronizing with repetitive optical phenomena. The integration of such repetitive phenomena makes it possible to detect and measure extremely weak signals in the IR region of up to 1600 nm using an S-1 streak tube.	200 to 850 nm (S-20) 300 to 1600 nm (S-1)	M6863	> 1 : 200
			M6861	> 1 : 1000
C6138 (FESCA-200)	The FESCA-200 is an ultrafast streak camera with a temporal resolution of 200 femtoseconds (typ.). It is designed for use with single-shot or slow-repetitive phenomena. It can analyze the process of energy relaxation and dynamics of chemical reaction in the femtosecond region in combination with femtosecond pulse laser.	280 to 850 nm (S-20)	built-in the main body	> 1 : 40
C5680	This is the streak camera which is most ideal for general purposes. By selecting the appropriate sweep units and additional function units, this can be configured to cover an extremely wide range of times from 200 ps to 1 ms. In addition, it is capable of measuring anything from a single event phenomenon to high-repetition phenomena in the GHz range. The appropriate streak tube (photocathode) can be selected to accommodate light ranging from X-rays to the near infrared rays. Operation can be handled very simply using a computer.	200 to 850 nm (N5716, N5864) 300 to 1600 nm (N5716-02) 115 to 850 nm (N5716-01) 400 to 900 nm (N5716-03) X-ray region (10 eV to 10 keV)	M5676	> 1 : 30
			M5677	> 1 : 200
			M5675	> 1 : 1000
C4334	The C4334 ("Streakscope") is a compact streak camera primarily dedicated for time-resolved as an alternative to conventional detector system.	200 to 850 nm (C4334-01) 400 to 900 nm (C4334-02) 300 to 1500 nm (C4334-04)	built-in the main body	> 1 : 70
C2830	This streak camera is designed for single-sweep operations, and offers a maximum temporal resolution of 10 ps.	200 to 850 nm (S-20)	M2547	> 1 : 100
			M2548	> 1 : 200
C7700	The C7700 is a wide dynamic range streak camera for single shot measurement.	200 to 850 nm (S-20) 300 to 1600 nm (S-1)	built-in the main body	> 1 : 10000
C4187	This is a large format streak camera with 18 mm effective photocathode width (three times that of the C5680 model). In addition to high and low speed sweep operations, framing operation is possible.	200 to 850 nm (S-20)	M4190	> 1 : 50
			M4191	> 1 : 100
C4575-01	The C4575-01 X-ray Streak Camera offers extremely high temporal resolution of only 1.5 picoseconds, while maintaining good spatial resolution. This is made possible by using the latest achievements in streak tube technology.	X-ray region (10 eV to 10 keV)	built-in the main body	—

Maximum sweep repetition frequency	Temporal resolution	Sweep range (sec/full scall) 10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2}	Model No.
2 MHz	< 50 ps	5 ns – 10 ms	C6860 (Synchroscan Fesca)
75 to 100 MHz	500 fs	50 ps – 2 ns	
100 Hz	< 200 fs	60 ps – 1.2 ns	C6138 (FESCA-200)
10 KHz	< 2 ps	200 ps – 50 ns	C5680
2 MHz	< 50 ps	5 ns – 1 ms	
75 to 165 MHz	< 2 ps	200 ps – 2 ns	
2 MHz	< 15 ps	1 ns – 10 ms	C4334
1 KHz	< 10 ps	500 ps – 10 ns	C2830
10 KHz	< 100 ps	10 ns – 1 ms	
1 KHz	< 5 ps	1 ns – 1 ms	C7700
500 Hz	< 100 ps	10 ns – 1 ms	C4187
500 Hz	< 10 ps	2 ns – 50 ns	
50 Hz	< 1.5 ps	160 ps – 2 ns	C4575-01

5 Definitions of Terms

[Time Characteristic/Unit/Gate/Trigger]

• Temporal Resolution

This is the boundary of the resolution which distinguishes between two events which are consecutive in terms of time. In HAMAMATSU catalogs, the temporal resolution is defined as the FWHM (full width at half maximum) of the intensity of the streak image in relation to an incident light pulse whose temporal width (pulse width) can be infinitely close to but not equal to zero.

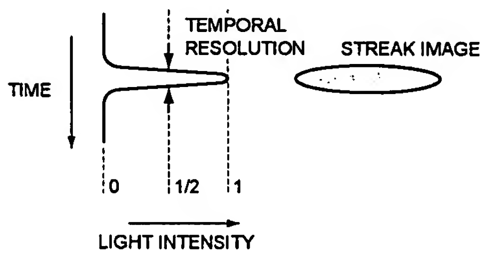


Fig. 4 Temporal Resolution

• Picosecond (ps)/Femtsecond (fs)

One picosecond is equal to one-trillionth of a second (10^{-12} second). Light in vacuum travels 0.3 mm in a picosecond.
One femtosecond is equal to 1/1000th of a picosecond (1/one thousand trillionth of a second, or 10^{-15} second).

• Gate

This is an operation carried out in order to render the streak camera temporarily insensitive.
If light positioned before and after the light in the field being measured is allowed to enter the streak camera, the photoelectrons produced by that light will be scattered and multiplied inside the streak tube, causing optical noise to appear on top of the actual streak image, and lowering the S/N of the streak image. In order to prevent this problem, the streak camera is equipped with a cathode gate which blocks the photoelectrons produced on the photocathode and an MCP gate which stops electrons from being multiplied in the MCP.

• Gate Extinction Rate

This is the ratio of the phosphor screen brightness when the gate is open and when it is closed, in relation to incident light which is constant in terms of time.

• Dynamic Range

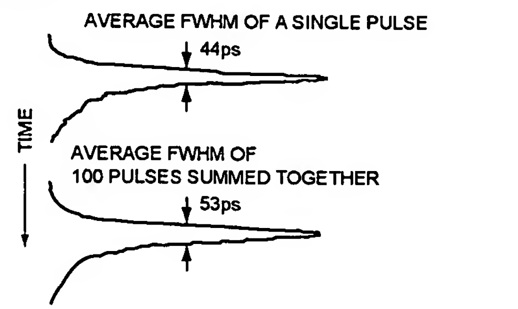
This indicates the light intensity range which can be measured with the streak camera. In this booklet and HAMAMATSU catalogs, the dynamic range is specified as the weakest pulse which can actually be measured, instead of the noise level, which has conventionally been used to define the dynamic range. In other words, the ratio between the strongest pulse and the weakest pulse in the range of the input/output linearity ($\gamma = 1$) is taken as the dynamic range. Generally speaking, there is a tendency for the dynamic range to become lower as the temporal resolution improves.

• Trigger Delay

In order to obtain a streak image in the center of the phosphor screen, the trigger signal has to arrive at the slit earlier than the incident light. The trigger delay is used to achieve this difference in timing.

• Trigger Jitter

When a phenomenon is being repeated in order to measure it (streak images are being summed), the position of the streak image on the phosphor screen jumps slightly each time the phenomenon is repeated, because of fluctuation in the operation timing of the sweep circuit and other factors. This fluctuation is called trigger jitter, and is one element which limits the temporal resolution of the system. It can be a particular problem with high-speed sweeps. (With low-speed sweeps, the trigger jitter is lower than the time resolution, and can be ignored.)
The trigger jitter is determined by the difference between the FWHM of a single pulse and the FWHM when pulses are summed together.



IN THIS CASE, THE TRIGGER JITTER IS CALCULATED, AS SHOWN IN THE FOLLOWING EQUATION, TO BE ±15ps OR LESS.

$$T_j = (53^2 - 44^2)^{1/2} = 29.5\text{ps} \ (< \pm 15\text{ps})$$

Fig. 5 Determining Trigger Jitter

[Sweep Method/Measurement Method]

• Single-Sweep

Essentially, this term comes from the fact that only one sweep is involved (a single shot). In this booklet and in HAMAMATSU catalogs, however, we use the term to refer to any sweep ranging from a single shot to sweeps with a repetition rate of up to tens of kHz. The measurement range which covers this sweep method is from 60 ps to 10 ms. A ramp voltage is applied to the deflection (sweep) electrodes during the sweep. (see Fig. 6)

• Synchroscan

This refers to a high-speed repeated sweep in which a high-frequency sinewave voltage is applied to the deflection electrodes (see Fig. 6). By synchronizing the repeated sweep frequencies, streak images can be accumulated (integrated) at a fixed position on the phosphor screen. This allows very faint optical phenomena to be measured with a high S/N.
The repetition of the optical phenomenon is the same as the sweep frequency, but it must be an integral multiple or an integral fraction of the sweep frequency. The temporal measurement range is from several hundred ps to 2 or 3 ns.

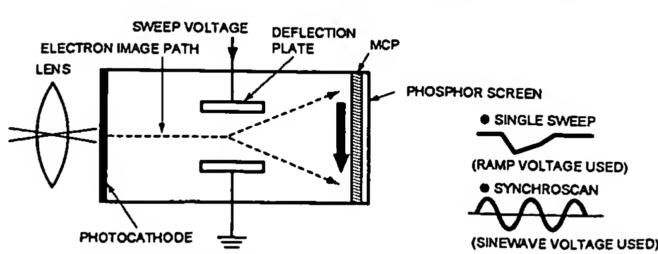


Fig. 6 Sweep Voltages for Single-sweep and Synchroscan

• Synchronous Blanking

With the synchroscan method, because only vertical deflection plates are used and repeated sweeps carried out in the vertical direction, if there is incident light during the return sweep (the sweep from the bottom back to the top), this will overlap the signal of the main sweep (the sweep from the top to the bottom) as a suprious-signal. This makes it very difficult to obtain accurate measurements.

In synchronous blanking, a sinewave with a phase different from that of the vertical sweep signal is applied to the horizontal deflection plates, and the return sweep is forced off its course in the horizontal direction. As shown in Fig. 10, the return sweep thus misses the phosphor screen, allowing only the main sweep to be measured, and this enables accurate measurement of high-speed repeated phenomena up to the GHz range.

Comparison of Methods of Observing a 1.5μm Semiconductor Laser (modulated at 2GHz)

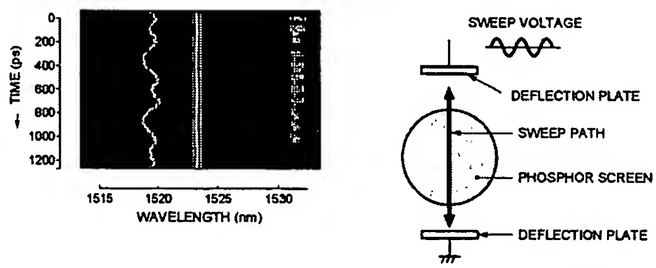


Fig. 7 Sweep Path Using Synchroscan

The image resulting from incident light during the return sweep overlaps with the signal from the main sweep.

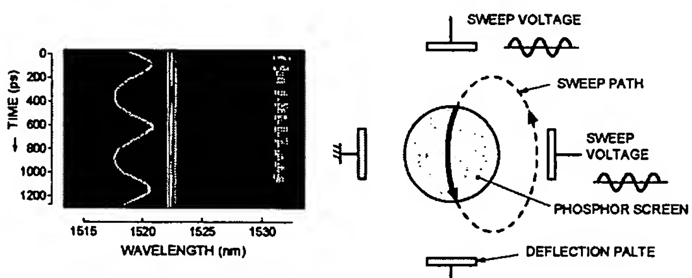


Fig. 8 Sweep Path Using Synchronous Blanking

The use of elliptical sweep so that the return sweep does not pass over the phosphor screen enables measurement of only the signal from the main sweep. (The photo was obtained using the data analyzer to perform vertical compensation for streak image bending.)

• Dual Time Base

In addition to the synchroscan, by appling a ramp voltage to the horizontal deflection plates, the repeated vertical sweep shifts in the horizontal direction (horizontal sweep). This allows temporal imformation to be captured in the horizontal direction as well as the vertical direction. The vertical axis represents the fast time axis, while the horizontal axis shows the slow time axis. By having two time axis, it is possible, for example, to measure pulse widths and phase fluctuations which are sufficiently longer than the repetition frequency of events which repeat at high-speed.

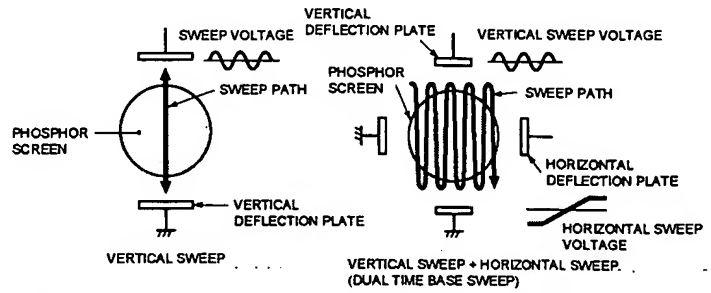
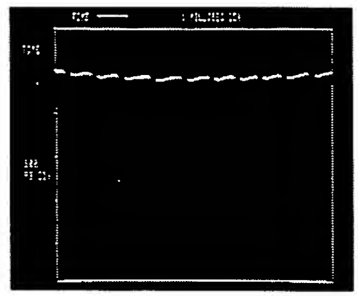


Fig. 9 Sweep Path Using Dual Time Base



Jitter measurement example of a mode-locked YAG laser and a sync pump dye laser excited by the YAG laser's second harmonic
(top: dye laser, bottom: YAG second harmonic)

• Photon Counting Integration

Photoelectrons given off from the photocathode of the streak tube are multiplied at a high integration rate by the MCP, and one photoelectron is counted as one intensity point on the phosphor screen. A threshold value is then used with this photoelectron image to clearly separate out noise.

Positions in the photoelectron image which are above the threshold value are detected and are integrated in the memory, enabling noise to be eliminated completely. This makes it possible to achieve data measurements with a wide dynamic range and high S/N.

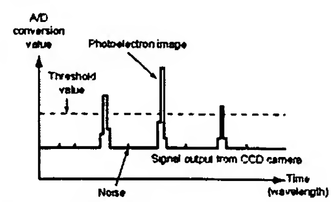


Fig. 10 Separation of Photoelectron Image and Noise

• Time-resolved Spectroscopy

In time-resolved spectroscopy, temporal fluetuation in the intensity of light at various wavelengths are measured. A spectroscope is set in front of the streak camera, and light separated in the horizontal direction is collected and an image formed at the level input slit in order to be measured. (See Application Examples ①, ②, and ③ on page 6.)

• Time and space-resolved Measurement

This is a type of measurement in which temporal fluctuation in the intensity of the light are measured at the position of the light being measured. This is done by using a lens system appropriate to optical images in the target range and forming an image on the input slit surface of the streak camera. (See Application Examples ④, ⑤, and ⑥ on page 7.)

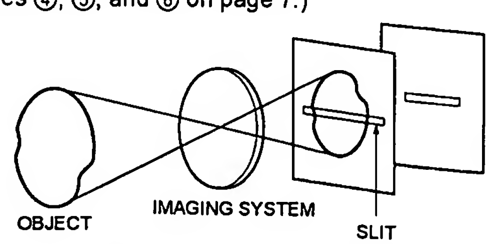
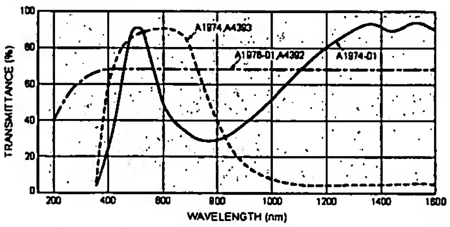


Fig. 11 Time and space-resolved Measurement

[Input/Output/Readout System/Optional]

• Input Optics

This is an optics which is positioned in front of the photocathode of the streak tube. Its function is to make the light being measured into fine slit ray and make it focused on the photocathode. It consists of a slit section and a lens section. Various models are available, classified by the spectral transmittance and brightness of the lens system.



Type No.	F. No.
A1974	1.2
A1974-01	1.2
A1976-01	5.0
A4392	4.5
A4393	1.2

Fig. 12 Spectral Transmittance and F-number of Input Optics

• Output Optics

This is an optics which is positioned between the phosphor screen on the output side of the streak tube and the camera used for readout. It is used to form an image on the sensitive surface of the camera which reads the streak image formed on the phosphor screen.

• Photocathode

This is configured of numerous layers of various types of metallic film, layered on the surface of the window material, so that when light strikes this surface, the light energy is absorbed and electrons called photoelectrons are emitted. The wavelength range of the incident light from which these photoelectrons are generated, and the conversion efficieney, differ depending on the material making up the photocathode.

• Spectral Response Characteristics (See Page 15)

The percentage of photoelectrons emitted from the photocathode to the number input in the incident light varies depending on the wavelength of the light. This is called the spectral response characteristic and, depending on how definitions are used, it is expressed in terms of quantum efficiency and radiant sensitivity.

• Radiant Sensitivity

This indicates how many amperes (A) of photoelectric current are produced when 1 watt (W) of incident light is entered in the photocathode. It is expressed as the proportion of the incident light to the photoelectric current (A/W).

• Quantum Efficiency

This is the ratio between the number of incident photons on the photocathode and the number of photoelectrons generated. It is calculated using the following equation: No. of photoelectrons/ no. of incident photons × 100 (%).

• Phosphor screen

This is a screen which produces light when electrons bump against it. This is where the electron image is optically converted into a streak image. The phosphor screen consists of a glass plate and layers of fluorescent material on the surface of the plate. The amount of light generated by the fluorescent material is proportional to the kinetic energy of the electrons. The peak and attenuation time of the spectrum vary depending on the type of phosphor screen used. Phosphor screens are classified by P numbers, such as P-11, P-20 or P-43.

• MCP

This is an abbreviation for Micro Channel Plate. The MCP is an electron multiplier consisting of many thin glass capillaries (channels) with internal diameters ranging from 10 to 20 μm, bundled together to form a disk-shaped plate with a thickness of 0.5 to 1 mm. The internal walls of each individual channel are coated with a secondary electron emitting material, so that as the electrons come flying through the channels, they bump against the walls, and the repeated impact causes them to multiply in number. A single electron can be multiplied into as many as 10^4 using this process.

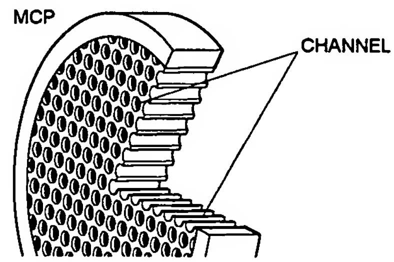


Fig. 13 MCP Configuration

• Material of Windows

This is a substrate formed by either the photocathode or the phosphor screen, and is made of material with a superb light transmission characteristic. Various materials such as MgF_2, UV transmitting glass, and fiber plate are used as window materials. The window material varies depending on the boundary transmittance wavelength of the UV region.

• CCD Camera

CCD cameras are the preferred devices for reading the images from the phosphor screens of streak cameras. Hamamatsu is offering various camera types; including cooled or non-cooled, digital or analog, slow-scan or fast-scan lens-coupled or fiber-optically coupled. So, the ideal CCD camera can be selected for a given streak camera model and application.

• Streak Trigger Unit (Frequency Divider)

This divides signals which have a repetition frequency too high to be handled by a single sweep unit, and supplies gate trigger signals and streak trigger signals to the single sweep unit.

• Delay Unit

This unit can be used to specify the delay time in steps as short as 30ps.

• PIN Photodiode

It is a device to convert the incident light pulse into the streak trigger signal for single sweep unit or synchroscan unit. For single sweep unit, a slow reptition pulse laser is used as the applicable light source. For synchroscan unit, a mode-locked laser is used as the applicable light source.

6 Reference Documents Pertaining to Streak Cameras

1 Condensed matter of semiconductor

- **Cooling of hot carriers in $Ga_{0.47}In_{0.53}As$**

H. Lobentanzer, H. J. Polland, W. W. Rühle, W. Stolz and K. Ploog Appl. Phys. Lett. 51 (9) 673 (1987)

- **Tunneling escape time of electrons from a quantum well under the influence of an electric field**

T. B. Norris, X.J. Song, W. J. Schaff, L. F. Eastman, G. Wicks, G. A. Mourou
Appl. Phys. Lett. Vol. 54, pp. 60-62, 1989 (Continued)

- **Time-of flight measurement of excitonic polaritons in a GaAs/AlGaAs quantum well**

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2 Photochemistry

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Tahei Tahara and Hiro-o Hamaguchi
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- **Development of a Streak-Camera-Based Time-Resolved Microscope Fluorimeter and Its Application to Studies of Membrane Fusion in Single Cells**

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Jeremy C. Hedden
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- **Picosecond Time-Resolved Emission Spectroscopy Using a Single-Photon Sensitive Synchroscan Streak Camera**

M. Yamashita, S. Kobayashi and M. Ishikawa
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- **Dynamics of laser-ablated particles from high Tc superconductor YBa_2Cu_3Oy**

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K. Nagase, K. Funatsu and I. Haga
Lecture Theses of the 7 th International Combustion Engine Symposium, Japan., No. 123, 1988
(Written in Japanese)

5 Research of Lasers

- **Pulse shortening of actively mode-locked diode lasers by wavelength tuning**

M. Serenyi, and J. Kuhl. E. O. Gobel
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- **InGaAsP monolithic extended-cavity lasers with integrated saturable absorbers for active, passive, and hybrid mode locking at 8.6 GHz**

P. B. Hansen, G. Raybon, U. Koren et al
Appl. phys. Lett. 62 (13), pp. 1445-1447, 1993

- **Applications of synchroscan and dual-sweep streak camera techniques to free-electron laser experiments**

Alex H. Lumpkin
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- **Optical diagnostics for a ring resonator free-electron laser**

M. L. Laucks, A. R. Lourey, D. H. Dowell et al
Optical Engineering, Vol. 32, No. 2, pp. 384-394, 1993

6 Optical Communications

- **Direct measurement of chromatic dispersion in single-mode fibres using streak camera**

K. Mochizuki, M. Fujise, H. Suzuki, M. Watanabe, M. Koishi and Y. Tsuchiya

- **lOOGbit/s optical signal generation by time-division multiplication of modulated and compressed pulses from gain-switched distributed feedback (DFB) laser diode**

A. Takada, M. Saruwatari
Electron. Lett. 24, pp. 1406-1408, 1988

- **Amplification of high repetition rate picosecond pulses using an InGaAsP traveling-wave optical amplifier**

G. Eisenstein, P. B. Hansen, J. M. Wiesenfield, R. S. Tucker, G. Raybon
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- **64Gb/s All-Optical Demultiplexing with the Nonlinear Optical-Loop Mirror**

P. A. Andrekson, N. A. Olsson, J. R. Simpson et al
IEEE PHOT. TEC. LETTERS, Vol. 4, No. 6, 1992

- **Laser-diode driven ultrafast all-optical switching by using highly nonlinear chalcogenide glass fiber**

Masaki Asobe, Hideki Kobayashi, Hiroki Itoh and Terutoshi Kanamori
OPTICS LETTERS, Vol. 18, No. 13, 1993

7 Electron Beam

- **Transverse and longitudinal beam profile measurement using optical techniques in TRISTAN accumulation ring**

A. Ogata, T. Ieiri, K. Nakajima and Y. Mizumachi
IEEE Transactions on Nuc. Sci. Vol. NS-32, pp. 1944-194, 1985

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S. Owaki
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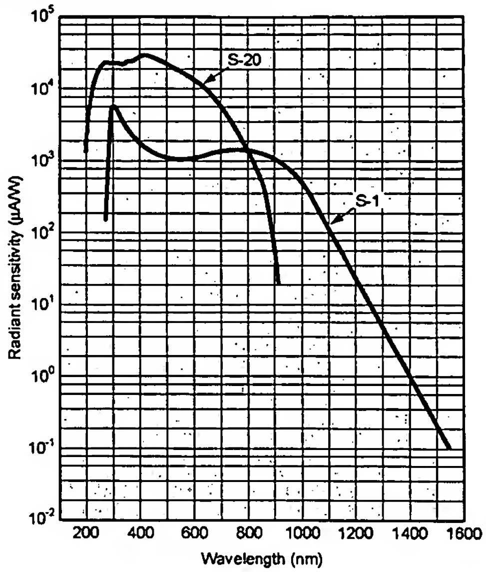
- **Measurement of bunch lengthening in TERAS**

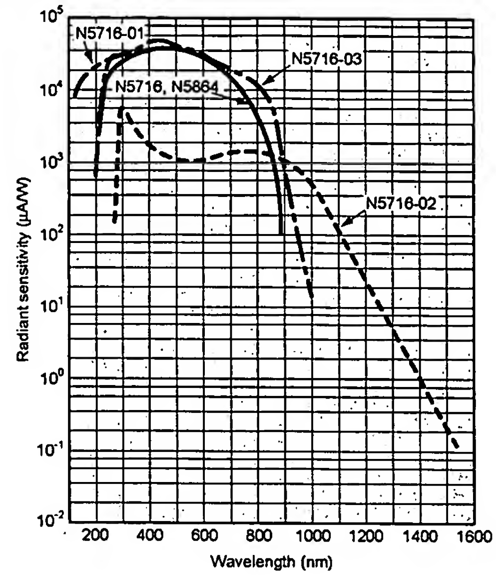
S. Sugiyama, T. Yamazaki, T. Noguchi, et al
Rev. Sci. Instrum. 60 (7), pp. 1748-1751, 1989

7 Spectral Response Characteristics of Streak Cameras

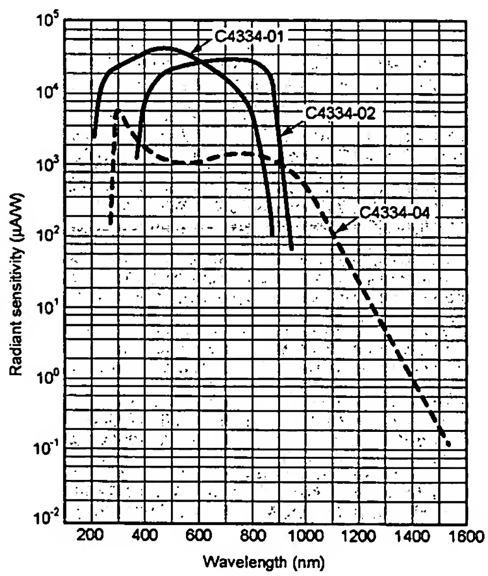
• **C6860 (Synchroscan FESCA)**



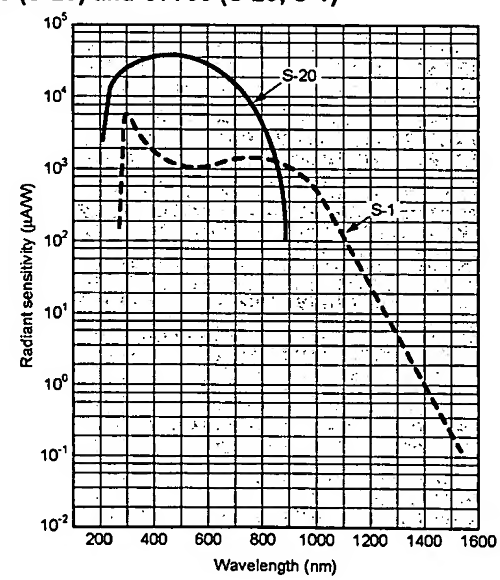
• **C5680 Series**



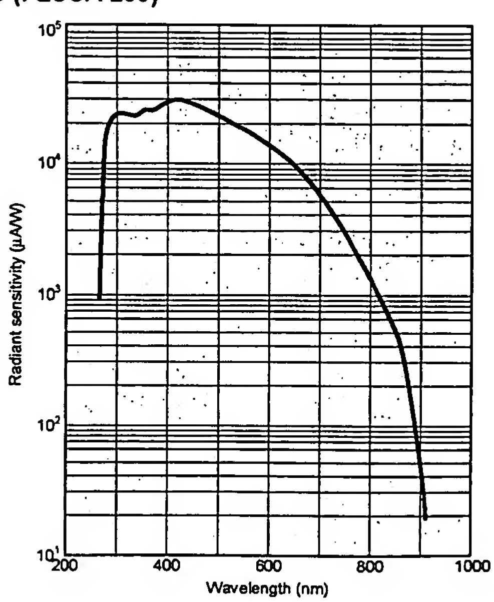
• **C4334**



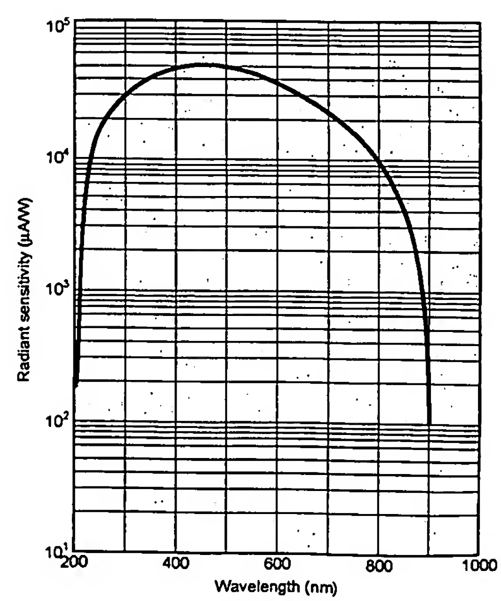
• **C2830 (S-20) and C7700 (S-20, S-1)**



• **C6138 (FESCA-200)**



• **C4187**



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HAMAMATSU PHOTONICS K.K., Systems Division
812 Joko-cho, Hamamatsu City, 431-3196, Japan, Telephone: (81)53-431-0124, Fax: (81)53-435-1574, E-mail:export@sys.hpk.co.jp

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Germany: Hamamatsu Photonics Deutschland GmbH: Arzbergerstr. 10, D-82211 Herrsching am Ammersee, Germany, Telephone: (49)8152-375-0, Fax: (49)8152-2658, E-mail: info@hamamatsu.de
France: Hamamatsu Photonics France S.A.R.L.: 8, Rue du Saule Trapu, Parc du Moulin de Massy, 91882 Massy Cedex, France, Telephone: (33)1 69 53 71 00, Fax: (33)1 69 53 71 10, E-mail: infos@hamamatsu.fr
United Kingdom: Hamamatsu Photonics UK Limited: 2 Howard Court, 10 Tewin Road, Welwyn Garden City, Hertfordshire, AL7 1BW, U.K., Telephone: (44) 1707-294888, Fax: (44) 1707-325777, E-mail: info@hamamatsu.co.uk
North Europe: Hamamatsu Photonics Norden AB: Smidesvägen 12, SE-171-41 Solna, Sweden, Telephone: (46)8-509-031-00, Fax: (46)8-509-031-01, E-mail: info@hamamatsu.se
Italy: Hamamatsu Photonics Italia S.R.L.: Strada della Moia, 1/E 20020 Arese (Milano), Italy, Telephone: (39)02-935 81 733, Fax: (39)02-935 81 741, E-mail: info@hamamatsu.it

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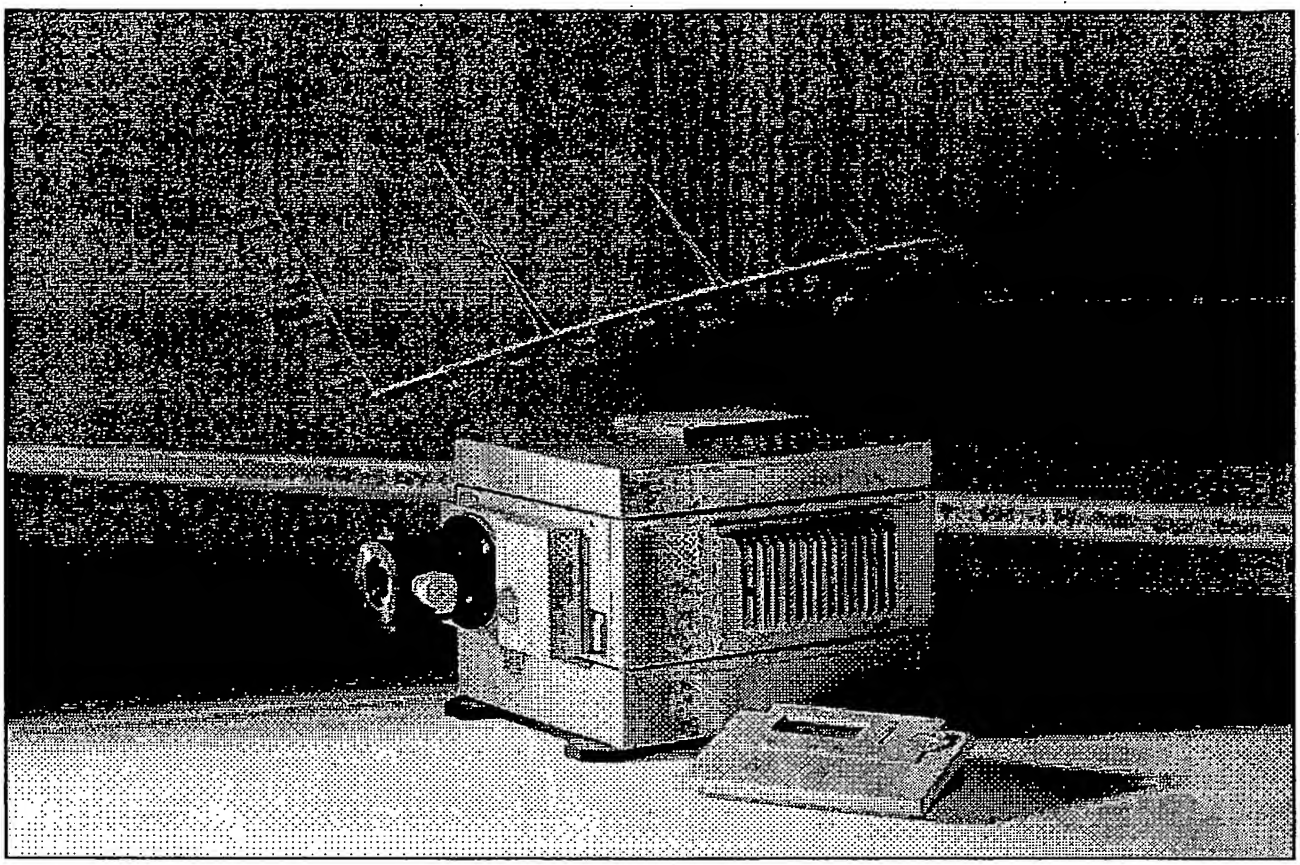
EXHIBIT B

ストリークカメラ (Streak camera)
C5680シリーズ (C 5680 series)

X線から近赤外領域の観測を2 psの時間分解能で実現。光現象に合わせて機能を選択。



ストリークカメラは、極めて短時間のうちに生じる発光現象をとらえる超高速光検出器です。測定対象からの光強度の時間的変化を優れた時間分解能で測定するだけでなく、光強度の空間分布(またはスペクトル)も同時に測定できます。

ストリークカメラC5680シリーズは、浜松ホトニクスが15年以上に渡り培ってきた高速光検出技術、画像計測技術等とノウハウを結晶させ完成したユニバーサル(汎用型)ストリークカメラです。従来品に比べ時間分解能が大幅に向上し、パーソナルコンピュータによる容易な操作を実現しました。

応用分野

シンクロトロンやライナックの電子バンチの測定

X線レーザ、自由電子レーザ、その他各種パルスレーザの研究

プラズマ発光、放電、レーザアブレーション、燃焼、爆発

蛍光寿命測定、過度吸収測定、時間分解ラマン

光ソリトン通信、量子デバイスの応答測定

ライダートムソン散乱、レーザ測距

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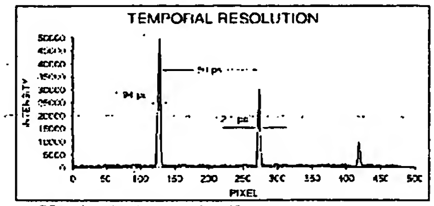
特長

● 時間分解能 2 ps 以内

シンクロスキャン掃引、単掃引ともに2 psの時間分解能を実現しました。



▲CPM ring dye laser, etalon 50 ps

● 単発現象から GHz 領域の高繰り返し現象まで対応

掃引ユニットの交換により、幅広い現象を測定することができます。

● X線から近赤外領域まで対応

ストリーク管（光検出部）を選択することにより、X線から近赤外までの幅広い測定が可能です。

● 時間軸・空間軸（波長軸）にわたる光強度を同時測定

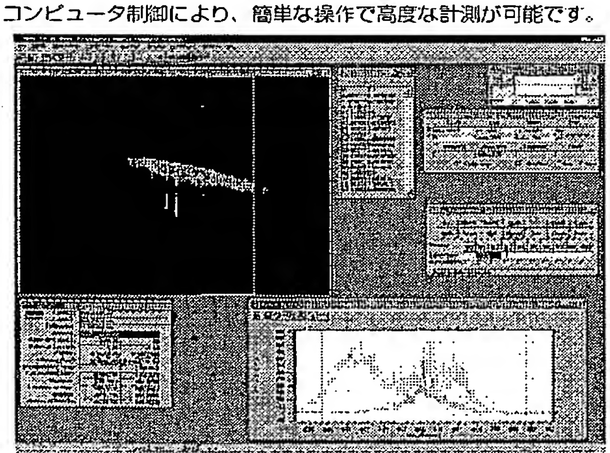
ストリークカメラの入射スリットの前にマルチチャンネル用の分光器を置くことにより、空間軸は波長軸になります。各波長における光強度の変化を測定(時間分解分光)することができます。

● 超高感度（単一光電子を検出）

ストリーク管は光を電子に変え、電子増倍する機構を備えていますので、肉眼では見えない弱い光を充分な光量まで増倍して観察することができます。極微弱光(シングルフォトン)領域まで検出可能です。
(フォトンカウンティング積算の原理参照)

● IEEE-488（GP-IB）制御

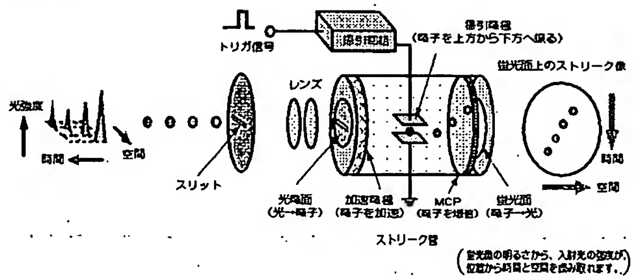
コンピュータ制御により、簡単な操作で高度な計測が可能です。



● 豊富な周辺装置

分光器、光トリガヘッド、遅延装置など豊富な周辺装置を用意しています。

動作原理

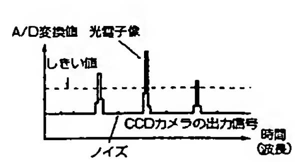


ストリークカメラの動作原理を上図に示します。
被測定光は、スリットを介してレンズ系により、ストリーク管の光電面上にスリット像として結像されます。今、時間的にも空間的にも少しづつずれ、光強度も異なる4つの光パルスがスリットに入射し、光電面に達したとします。
光電面は入射した光をその強度に応じた数の電子に変換するもので、ここで4つの光パルスは順次電子に変換され、加速電極により加速されて蛍光面に向って飛び出して行きます。
4つの光パルスによってできた電子群が掃引電極の間を通過する時、タイミングを合わせて掃引電極に印加された高電圧(上図参照)により、高速掃引(電子を上方から下方へ振る)が行われます。これにより、少しづつ遅れてやってきた電子群は垂直方向の少しづつ異なった角度に偏向され、MCP(マイクロチャンネルプレート)に飛び込みます。
電子群はMCPを通過する際、数1000倍まで電子の数を増倍された後、蛍光面に衝突し、再び光に変換されます。
蛍光面上では、最も早く入射した光パルスに対応する蛍光像が最も上方に位置し、順に下方へと配列されます。つまり、蛍光面上の垂直方向が時間軸になるわけです。また、それぞれの蛍光像の明るさは、それぞれの入射光パルスの強度に比例しています。蛍光像の水平方向の位置は、入射光の水平方向の位置に対応しています。

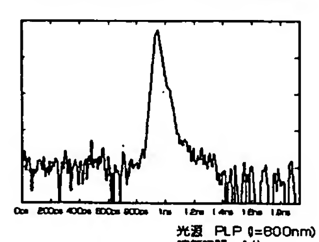
フォトンカウンティング積算の原理

ストリーク管の光電面から放出される光電子はMCPにより高増倍率で増倍され、1個の光電子は蛍光面上において1個の輝点として観測されます。この光電子像はしきい値を境に光電子像とノイズとを明確に分離することができます。

光電子像とノイズの分離



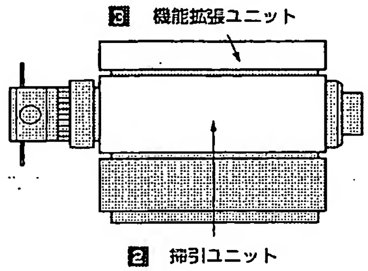
フォトンカウンティング積算

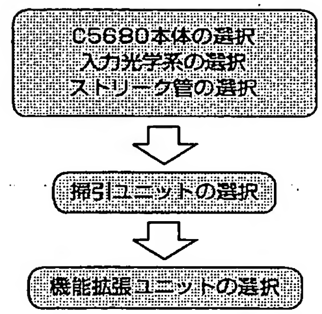


そこで、しきい値により光電子像の位置を検出しメモリ上で積算することにより、ノイズの全くない、高ダイナミックレンジ、高S/Nのデータ計測が可能となります。

機能構成 (Function constitution)

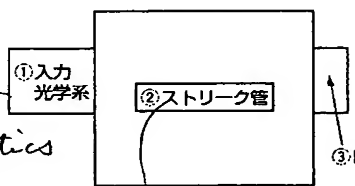
1 C5680本体（電源・カメラコントローラ付き）





仕様 (Specifications)

1 C5680本体 (C5680 body)



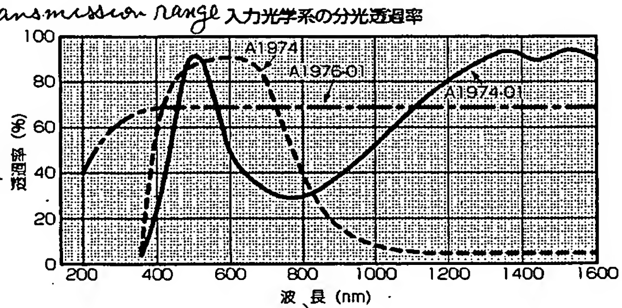
① 入力光学系 (Input Optics)

model name

型名	分光透過域	有効F値	倍率	スリット幅	スリット幅読み取り精度	全長
A1976-01	200 nm～1600 nm	5.0	1：1	0 mm ～5 mm	5 μm	98.2 mm
A1974	400 nm～900 nm	1.2	1：1			159 mm
A1974-01	400 nm～1600 nm	1.2	1：1			159 mm
A1976-04	200 nm～1600 nm	3.5	1：1			98.2 mm

A1974, A1974-01, A1976-04はオプションです。

light transmission range 入力光学系の分光透過率



② ストリーク管

型名	分光感度特性	有効光電面サイズ	MCPゲイン	蛍光面	空間解像度
N5716	200 nm～850 nm	0.15 mm×5.4 mm レンズ出力型	3×10^{3}	・蛍光面特性P43 ・ファイバ出力 ・有効蛍光面サイズ ・φ15 mm	光電面中心 25 lp/mm 以上
N5716-02	300 nm～1600 nm				
N5716-01	115 nm～850 nm				
N5716-03	200 nm～900 nm				
N5864	200 nm～850 nm		3×10^{5}		

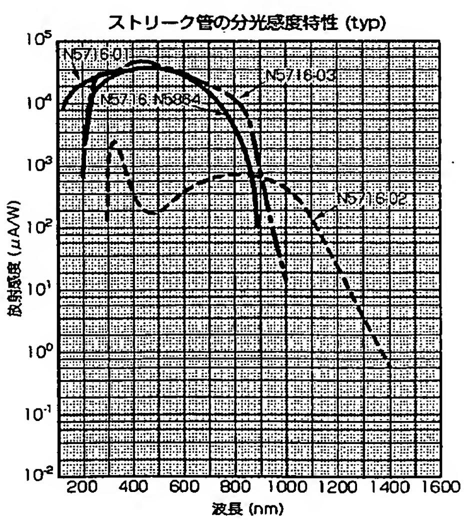
＊0 eV～10 keV対応のX線ストリークカメラも選択できます。

【サフィックス(型名副番)】

C5680はストリーク管の種類と出力方式により、次のようにサフィックスで分類されます。

C5680−0□ ・・・・・・・・ 1 200 nm～850 nm対応/MCP1枚
2 300 nm～1600 nm対応/MCP1枚
3 115 nm～850 nm対応/MCP1枚
0 レンズ出力型 4 200 nm～900 nm対応/MCP1枚
5 200 nm～850 nm対応/MCP2枚

ストリーク管の分光感度特性 (typ)



③出力方式

● レンズ出力…… 増倍率 1:0.7(50 mm:35 mm)
有効F値 F/2.0
Fマウント

④5680本体その他

●ゲート

ゲート方式	消光比	ゲート時間
MCP+水平ブランキング	1:10⁴以上	50 ns～連続
MCP+水平ブランキング+光電面	1:10⁶以上	50 ns～連続

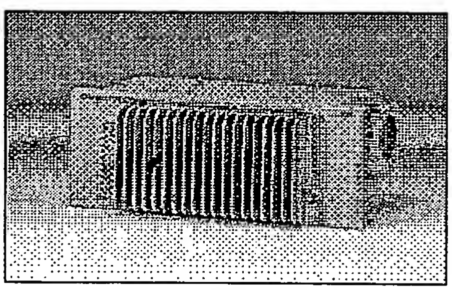
・ゲートトリガ入力......................................3.5 V～5.0 V/50 Ω
・ゲートトリガ遅延時間..............................120 ns 以下
・水平ブランキング最大繰り返し周波数....2 MHz
・MCPゲート最大繰り返し周波数............10 kHz
・光電面ゲート最大繰り返し周波数..........10 kHz

● モニタアウト信号 ....3.5 Vp-p(typ.)
● インターフェース ....IEEE-488(GP-IB)
● ステータス出力.........Dサブコネクタ DB-25S, 16 bit パラレル出力/オープンコレクタ
● 電源.............................AC 100 V/117 V/220 V/240 V, 50 Hz/60 Hz
● 消費電力.............. .....約180 V·A

2 掃引ユニット（プラグイン方式で本体に組み込み方式）

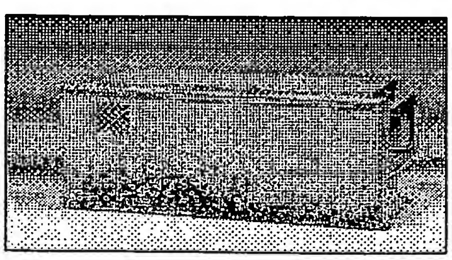
● シンクロスキャンユニット M5675

時間分解能............................2 ps以内（800 nm）
（3 ps以内:N5716-02使用時）
掃引時間　レンズ出力型....200 ps～1/6 fs
（fs:シンクロスキャン周波数）
掃引レンジ...........................4レンジ切り替え
シンクロスキャン周波数....75 MHz～165 MHzの範囲で選択
同調周波数範囲...................fs±0.2 MHz
（fs:シンクロスキャン周波数）
トリガジッタ.......................時間分解能以下
トリガ信号入力...................－3 dBm～17 dBm/50 Ω



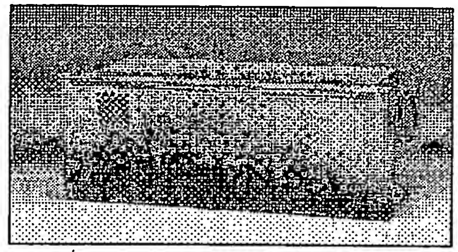
● 高速単掃引ユニット M5676

時間分解能............................ 2 ps以内(1.5 ps typ.)(800 nm)
掃引時間
ビデオ出力型......0 ns.15 ns, 0.5 ns, 1 ns, 2 ns, 5 ns, 10 ns, 20 ns, 50 ns/全画面
レンズ出力型......0.2 ns, 0.5 ns, 1 ns, 2 ns, 5 ns, 10 ns, 20 ns, 50 ns/全画面
トリガジッタ .... ±20 ps以下
トリガディレイ...................... 約13 ns(最速レンジ)
最大掃引周波数...................... 10 kHz
トリガ信号入力...................... ±5 V/50 Ω



● 低速単掃引ユニット M5677

時間分解能 .... 50 ps以内
掃引時間 .... 5 ns～1 ms/全画面
トリガジッタ .... 時間分解能以下
トリガディレイ .... 約 45 ns(最速レンジ)
最大掃引周波数 .... 2 MHz
トリガ信号入力 .... ±5 V/50 Ω

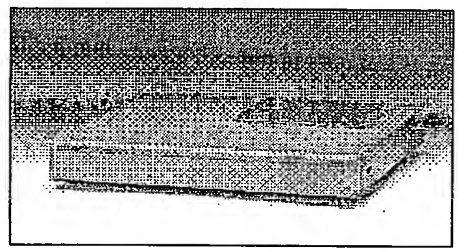


3 機能拡張ユニット（本体上部に接続）

● シンクロナスブランキングユニット M5678

（M5675シンクロスキャンと併用専用です。）

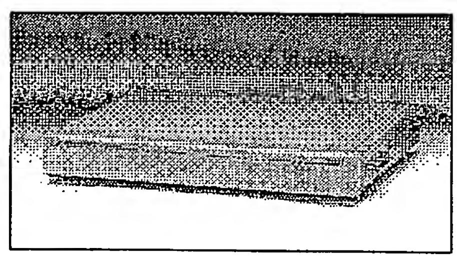
シンクロスキャン周波数...75 MHz～165 MHzの範囲内で選択
水平シフト幅.....................2.5 mmまたは11 mm（蛍光面上）



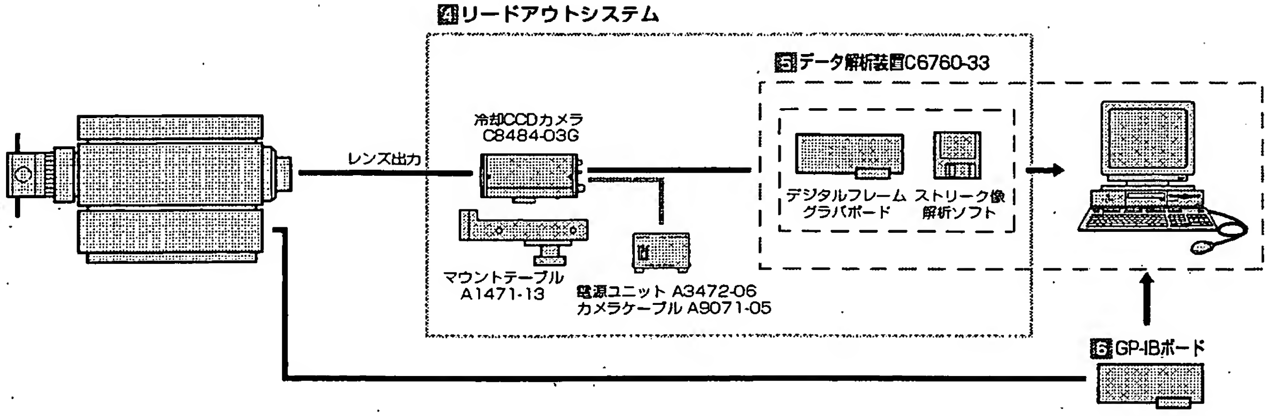
● 2時間軸拡張ユニット M5679

（全ての掃引ユニットと併用して使用できます。）

掃引時間 .... 100 ns～100 ms/全画面
最大掃引周波数 ....10 Hz
トリガ信号入力 .... ±5 V/50 Ω



読み出し装置



4 リードアウトシステム

		デジタル信号(C5680-0X用)
解像度（有効画素数）		1344(V)×1024(V)
リードアウトカメラ	型名	C4742-95-12ER
	露光時間	10 μS～10 s
	フレームレート(2×2ビニング)	最大16 Hz
	A/D コンバータ	12 bit

6 GP-IBボード

● KEYHLET 社製KPCI-448

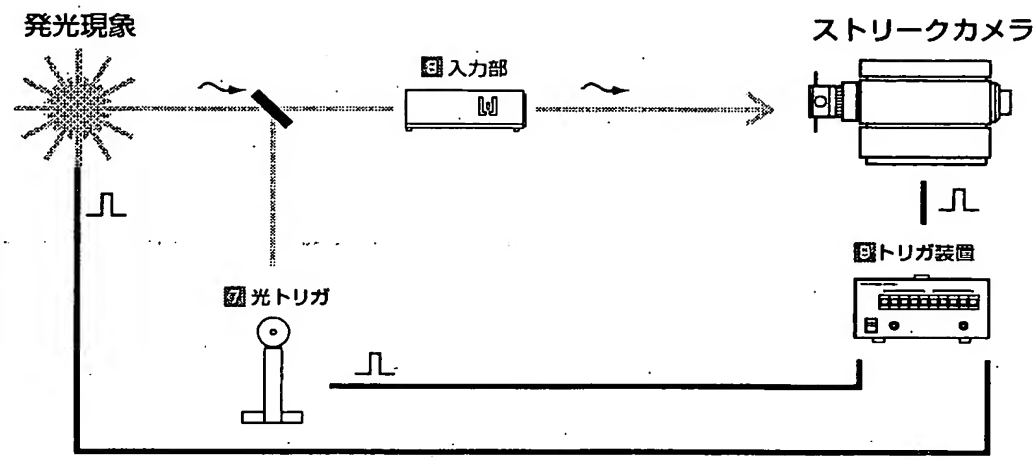
5 データ処理部　C6760-33 (Dos/V用)

本体	DOS/V 機 Pentium4　2 GHz 以上
内蔵メモリ	512 MB 以上
システム	Windows 2000/Windows XP
ディスプレイ	1280×1024 SXGA推奨

● ストリーク像解析ソフトウエア (Dos/V用)

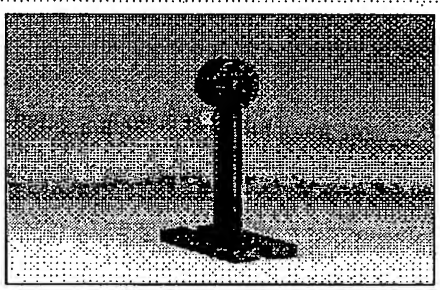
データ取得	モニタリング、アナログ積算、フォトンカウンティング積算
外部制御	C5680シリーズ、C5094分光器(C5095)
プロファイル解析	リアルタイム表示、半値幅、最大値、面積等
3次元表示	–
補正	暗電流、感度ムラ、湾曲、時間軸、波長軸、ジッタ
軸設定	チャンネル、時間、波長
ファイル形式(画像)	バイナリ(オリジナル16 bits)、TIFF、ASCII、DDE
ファイル形式(プロファイル)	ASCII、DDE
印刷機能	画像、プロファイル
その他	LUTコントロール、ズーム&スクロール、シフタ調整ステータス記録など

周辺装置



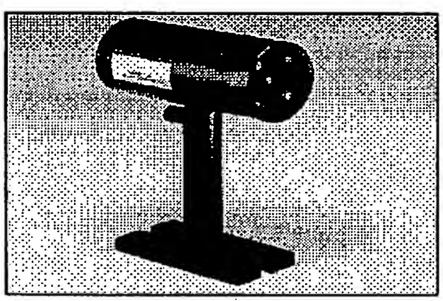
7 光トリガ (PINダイオードヘッド)

● PINダイオードヘッドC1083-01(低繰り返し用)



分光感度特性	400 nm~1100 nm
上昇時間	0.8 ns
寸法/質量 :ヘッド	100(W) mm×160 mm~235(H) mm×50(D) mm/400 g
:電源ユニット	100(W) mm×83(H) mm×100(D) mm/400 g
電源	+22.5 V(電池)

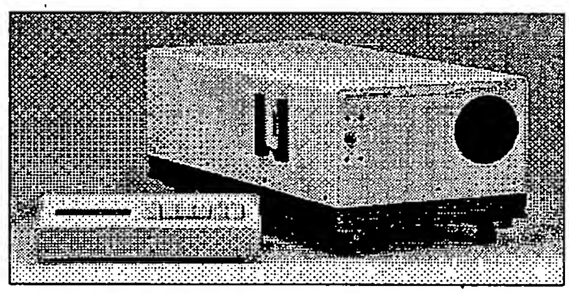
● PINダイオードヘッドC1808-02(高繰り返し用)



最小入力レベル	1 mW(f=80 MHz, λ=800 nm, FWHM<1 ps)
飽和出力レベル	約1.5 Vp-p (50 Ω)
周波数帯域	<100 MHz

8 入力部

● 分光器 C5094,C5095



	C5094	C5095
光学配置	ツェルニターナ型(収差補正トロイダルミラー付)	
焦点距離	250 mm	500 mm
F値	4	8
入射スリット幅	10 μm~2000 μm可変	
グレーティング	3枚まで同時装着可	
逆線分散	2.5 nm/mm (1200 gr/mm使用時)	1.5 nm/mm (1200 gr/mm使用時)
波長分解能	<逆線分散×0.06	

C5680と接続する場合、次の機器が必要です。

- 分光器用マウントテーブル
- 分光器用アダプタ
- 波長軸較正用光源(水銀ランプ等)

● ファイバ入力光学系(FCコネクタ) A6368

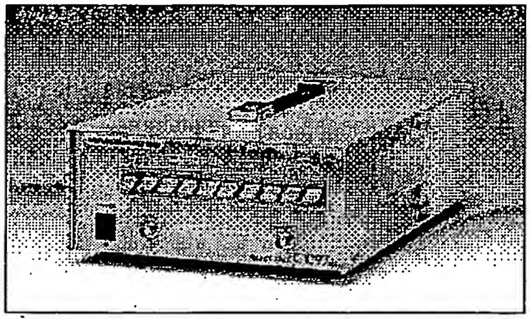
C5680の入射スリット部の代わりにこのファイバ入力光学系を接続できます。

● 対応レンズ

C5680の入射スリット部に、Cマウントアダプタを接続することにより、Cマウントの対物レンズの取り付けが可能です。またFCコンバータを介することによりFマウントの対物レンズも取り付けが可能です。

9 トリガ装置

● ディレイユニット C1097-01

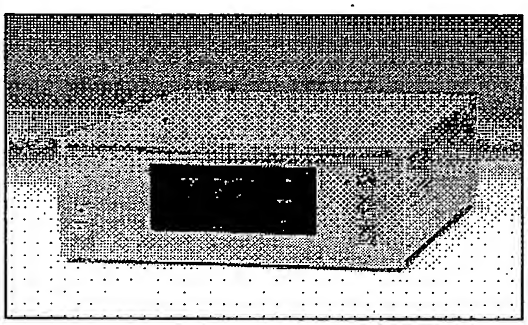


被測定現象とストリークカメラの動作タイミングを合わせるために用いられます。

ディレイ可変範囲	0 ns~31.96 ns
ディレイ設定レンジ	30 ps, 60 ps, 120 ps, 250 ps, 500 ps, 1 ns, 2 ns, 4 ns, 8 ns, 15 ns
最小ディレイ時間	約12 ns
最大入力電圧	30 V
電源	AC 85 V~AC 250 V
外形寸法/質量	215(W) mm×350(D) mm×102(H) mm/3.4 kg

* GP-IP インターフェースを搭載したC1097-04も用意しています。

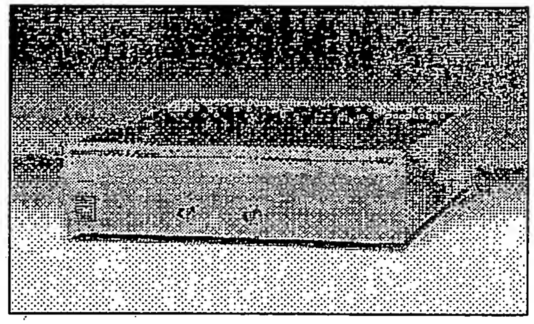
● 高安定型ディレイユニット C6878



シンクロスキャンユニットと組み合わせて使用され、トリガ信号のディレイ時間を調整するために用いられます。
また、掃引信号をモニタしながら、トリガ信号のディレイ量を自動的に調整しますので、長時間にわたり安定したストリーク像を得ることができます。

入力信号	INPUT ：入力信号周波数範囲	75 MHz~100 MHz
	入力信号レベル	0 dBm~+10 dBm
	REF.IN ：入力信号レベル	−10 dBm~+10 dBm
出力信号	OUTPUT：出力信号レベル	−3 dBm~+10 dBm
ディレイ可変範囲	INPUT信号に対する位相角	360 度
電源	入力電圧範囲	AC 100 V~AC 240 V
	入力電源周波数範囲	50 Hz/60 Hz
消費電力		約28 V・A
外形寸法		261 (W) mm×331 (D) mm×98.5(H) mm

● RFアップコンバータユニット C6207



10 MHzの入力信号に対してこれに同期した100 MHzの出力信号を出力します。
市販の周波数シンセサイザのリファレンス出力信号を入力することにより安定したシンクロスキャン用のトリガが得られます。

入力信号周波数	10 MHz±10 Hz
入力レベル	−10 dBm~0 dBm/50 Ω
出力周波数	100 MHz
出力信号レベル (typ.)	3 dBm/50 Ω
タイミングジッタ	σ:1 ps以下
電源	AC 100 V/117 V/220 V/240 V, 50 Hz/60 Hz

● ストリークトリガユニット C4547-02

外部トリガ信号よりゲートトリガ信号とストリークトリガ信号をつくり、単掃引ユニットに供給します。
分周機能がありますので単掃引ユニットの掃引繰り返し周波数よりも高い外部トリガ信号にも対応できます。

周波数帯域	10 MHz~200 MHz
入力レベル	0 dBm~15 dBm/50 Ω
出力信号レベル	3 Vp-p/50 Ω
出力周波数	1 Hz~100 kHz (可変)

● その他

デジタルディレイジェネレータDG535、ピコ秒ライトパルサPLPシリーズ等豊富な周辺機器を用意しています。お問い合わせください。

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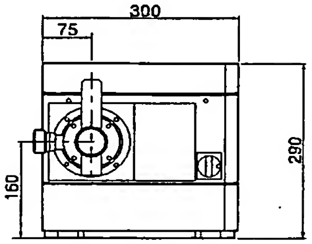
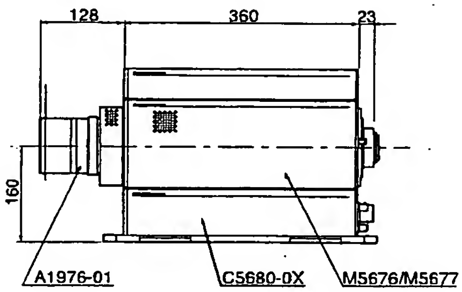
外形寸法図 (単位：mm)

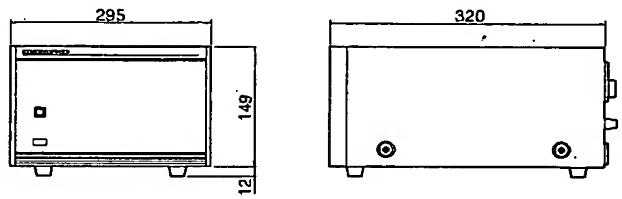
● ストリークカメラ C5680本体
（約20 kg）



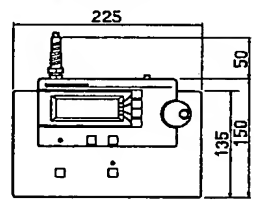
C5680-0X（レンズ出力）



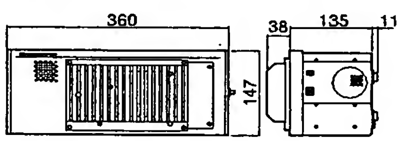
● 電源ユニット
（約10 kg）



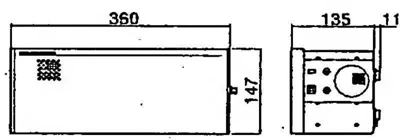
● リモートコントロールユニット
（約1.2 kg）



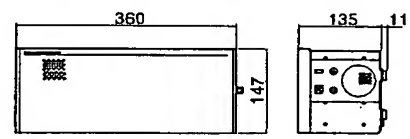
● シンクロスキャンユニット M5675
（約4.1 kg）



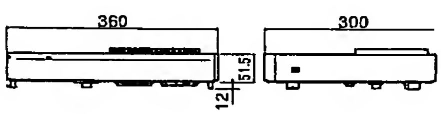
● 高速単掃引ユニット M5676
（約2.4 kg）



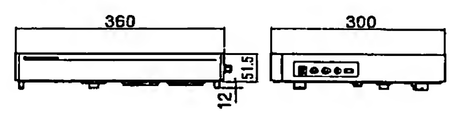
● 低速単掃引ユニット M5677
（約2.2 kg）



● シンクロナスブランキングユニット M5678
（約3.4 kg）



● 2時間軸拡張ユニット M5679
（約3.4 kg）



浜松ホトニクス株式会社

システム事業部 特機営業部
〒430-8587 浜松市砂山町325-6（日本生命浜松駅前ビル）
☎(053)452-2141（代表） ☎(053)452-2148（営業直通）
FAX(053)452-2139 E-mail salesi@sys.hpk.co.jp
Web site http://www.hpk.co.jp

東京支店 〒105-0001 東京都港区虎ノ門3-8-21（虎ノ門33森ビル）
☎(03)3436-0491 FAX(03)3433-6997

大阪営業所 〒541-0052 大阪市中央区安土町2-3-13（大阪国際ビル）
☎(06)6271-0441 FAX(06)6271-0450

仙台営業所 〒980-0011 仙台市青葉区上杉1-6-11（日本生命仙台勾当台ビル）
☎(022)267-0121 FAX(022)267-0135

HAMAMATSU

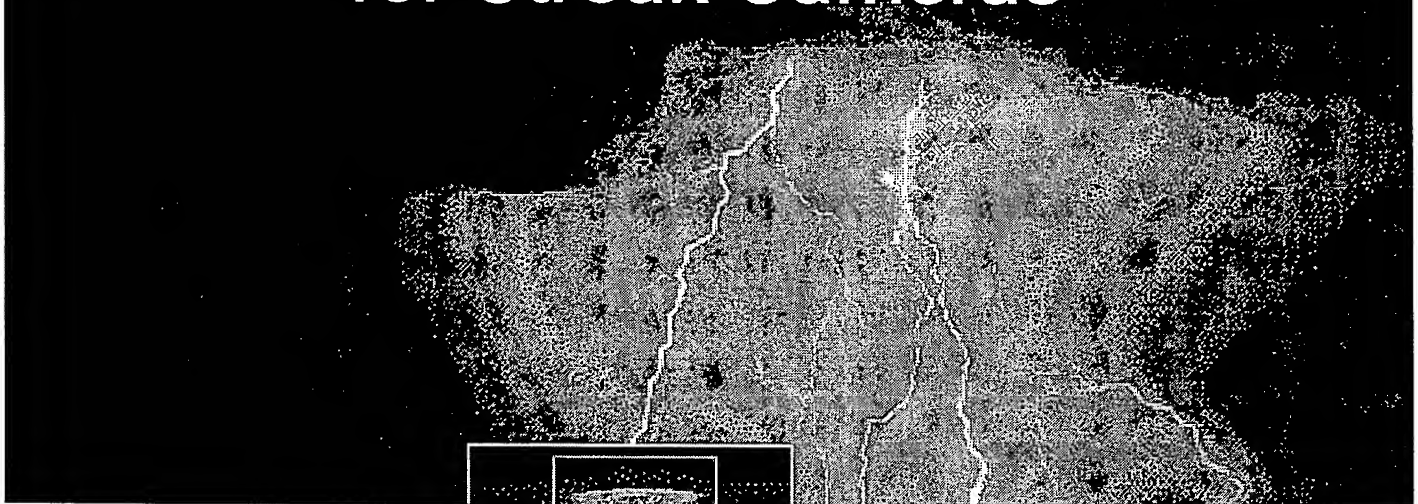
Cat.No.SSCS1053J09
APR/2005 HPK
(20)

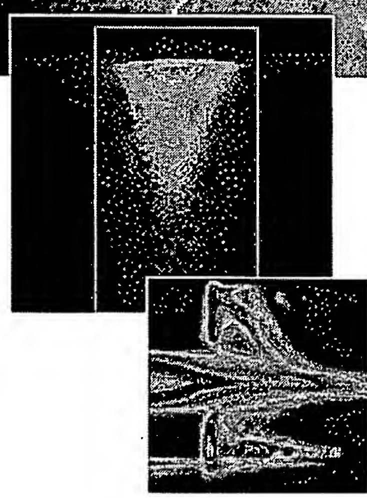
EXHIBIT C

HPD-TA

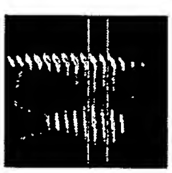
High-Performance
Digital Temporal Analyzer

Control & Readout System for Streak Cameras





- Integration of complete streak systems
- Powerful data acquisition
- Full data calibration
- Manual and semi-automatic operation
- Convenient Windows user interface



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HAMAMATSU

Overview

The HPD-TA Temporal Analyzer system is a high-performance digital control & imaging system, designed specifically for reading out the image on the phosphor screen of Hamamatsu streak and framing cameras. It provides precise, quantitative acquisition and preprocessing of two-dimensional streak and framing data, including a full range of data correction and calibration possibilities.

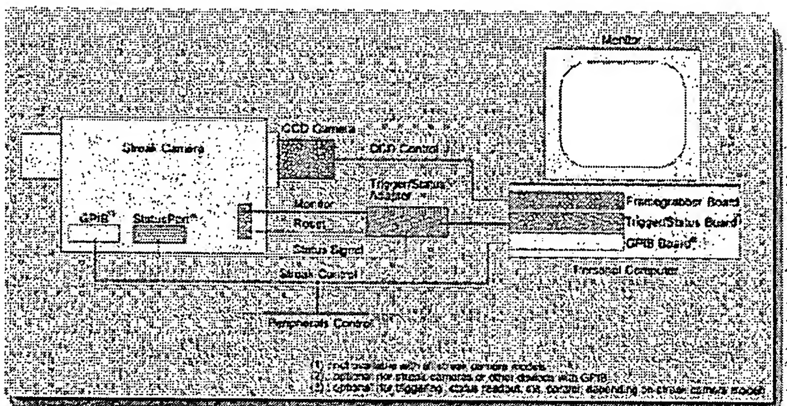
Moreover, it integrates the various hardware devices belonging to a complete streak setup into a single coherent system, and – as long as the used devices support remote control – can directly control all system components and their interrelations.

The HPD-TA program is a powerful and user-friendly 32-bit software, running under Microsoft Windows. It offers plenty of features based on our long-term experience and user feed-back.

Design of hardware support

Streak and Framing Cameras

HPD-TA supports all Hamamatsu streak and framing cameras, old and new models. Models with GPIB interface can be fully remote-controlled, while some other models can do a unidirectional information transfer via their so-called StatusPort. By these means, the HPD-TA software automatically knows about the selected operation mode (e.g. chosen time range) and will treat the data appropriately (e.g. activate the proper time axis calibration).



Basic hardware configuration

Further, HPD-TA can control shutters, tube gain, etc. automatically, preventing unnecessary stress of the streak tube. So, HPD-TA brings not only convenience but also safety to your valuable system.

CCD Cameras

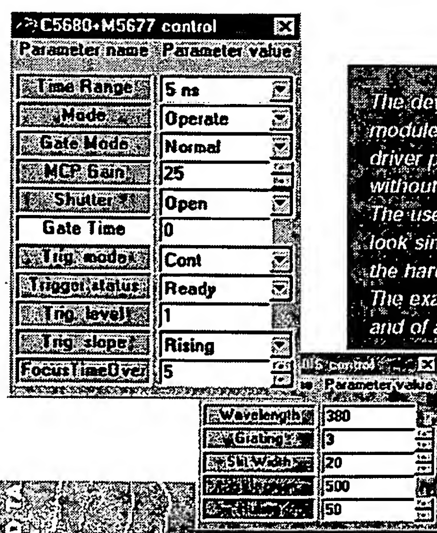
As readout devices, HPD-TA supports three different classes of CCD cameras, including digital and video types. (For a list, refer to the last page.) All special features of these cameras are fully supported.

The CCD camera is connected to an industry-standard personal computer via a high-speed frame grabber board, which allows real-time image data transfer and processing.

Accessory Devices

Besides these core devices, HPD-TA can also control a variety of other external devices that are frequently used in streak setups. At the time of this writing, around one dozen of those other devices are supported, including spectrographs, pulse generators, delay units, shutter devices, and others. (For a detailed list of currently supported devices, please consult Hamamatsu.)

By this versatility, HPD-TA enrolls these devices into one coherent measuring system, convenient and safe to use. Streak measurements have never been easier.



The device support is realized via "virtual devices", i.e. software modules that mirror the real devices. This is a modular design using driver plug-ins, which allows us to add or change drivers easily, without changing the rest of the program.

The user interface is realized via standardized control panels that look similar for all devices. These control panels facilitate controlling the hardware as well as displaying the current device status.

The examples on the left show the control panels of a streak camera and of a spectrograph.

HPD-TA

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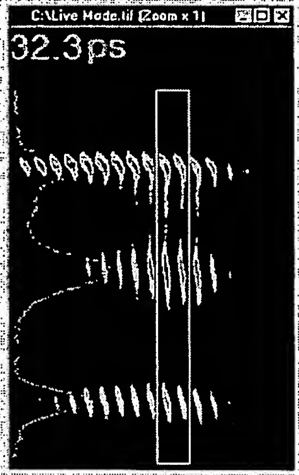
Data acquisition

Live Mode

Live Mode allows viewing the streak image on the PC monitor in real-time. It is mainly used for monitoring the time-resolved signal during jobs such as optical alignment, focussing, laser adjustment, and so on.

The sample picture on the right shows a time-resolved spectrum of a pulsed laser diode, as seen by a combination of a spectrograph with a synchroscan streak camera. (The time axis is vertical, the spectral axis is horizontal.) Along the time axis you can see the main pulse and relaxation oscillations, while the spectral axis shows the longitudinal LD modes. Also, frequency chirping is clearly revealed. Such complete two-dimensional time-resolved spectra can be observed in real-time – while adjusting experimental parameters like laser diode current, for instance.

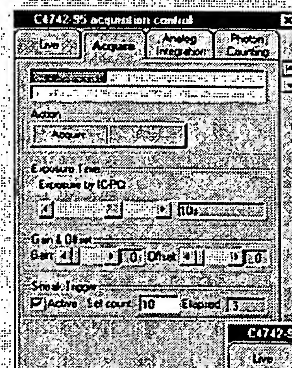


The intensity profile and the width (FWHM) of a pulse can also be displayed in real-time, which is very useful during adjustments.

Live Mode window

Single-Sweep Image Grabbing

In case of single-sweep streak cameras it is typically required to grab a single CCD image frame, synchronized with the streak camera and an external event. HPD-TA supports versatile trigger schemes facilitating this task, including handshake signaling with the streak camera in order to control trigger inhibition and to prevent accidental misfiring.



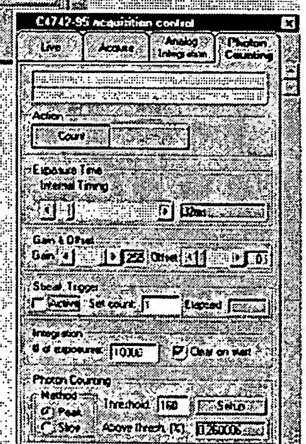
Single-sweep acquisition control

Analog and Photon Counting Integration

The measurement of very weak signals frequently requires longer integration times. HPD-TA offers a wide variety of integration modes, including on-chip integration and in-memory accumulation. By these methods, integration times ranging from a few ms to several hours can be realized.

If ultimate dynamic range of the measurement result is required, the user can also choose ***Photon-counting*** integration, a great feature for many applications such as fluorescence lifetime measurements and others. Photon-counting yields a near-Poissonian counting statistics, and a D-range of 10^5 or more can be achieved if the integration time is sufficient.

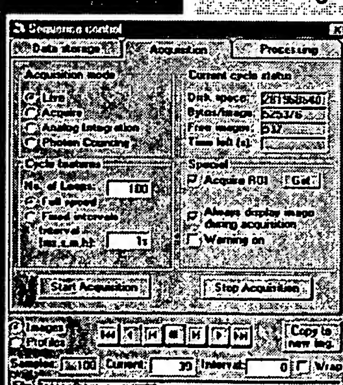
All kinds of integrations are performed in real-time, without skipping any signal.



Photon-counting integration control

Data integration can be combined with trigger handshaking, allowing precise control over the number of integrated events if required.

Recording Dynamic Phenomena



For the purpose of recording slow variations of streak image data over time, HPD-TA offers two dedicated tools.

Sequence Mode streams images or intensity profiles continuously into RAM or onto the hard disk. (RAM recording is real-time, while disk recording offers bigger capacity.) After recording, such sequences can be played back like a movie, and various image processing functions can be applied to the sequence at once, including averaging and jitter correction. Sequence recording works in combination with all above mentioned acquisition modes.

Dynamic Photon Counting records only the X-Y coordinates of photons. This allows extremely long integrations without the need for large storage capacity and is very useful for analyzing very slow phenomena. For example, the change of a time-resolved picosecond photon-counting spectrum due to slow sample kinetics can be analyzed.

Sequence recording control

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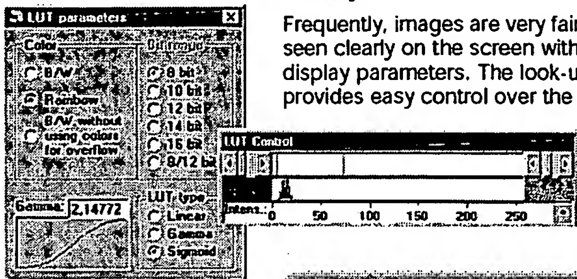
Image display

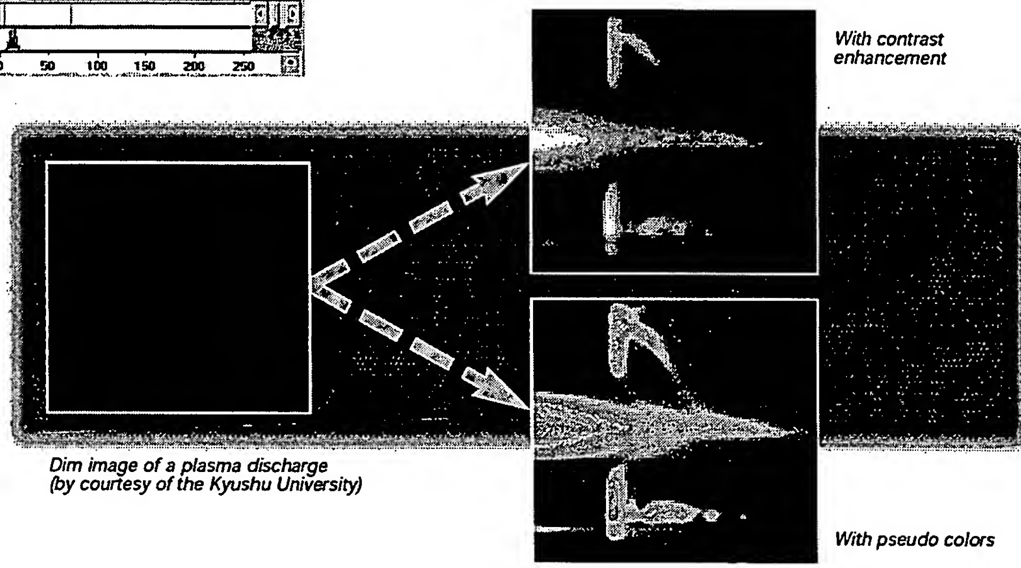
Images are displayed in image windows on the Windows desktop. The number of simultaneously displayed image windows is limited only by PC memory.

Frequently, images are very faint and cannot be seen clearly on the screen without manipulation of display parameters. The look-up-table (LUT) tool provides easy control over the image appearance by adjusting brightness, contrast and pseudo-colors, without changing any measurement data. By this means even the dimmest phenomena can be visualized clearly and brightly.

Also, image zoom & scroll is available for inspecting tiny details in an image.

These features work in real-time and in all acquisition modes, even in Live mode.





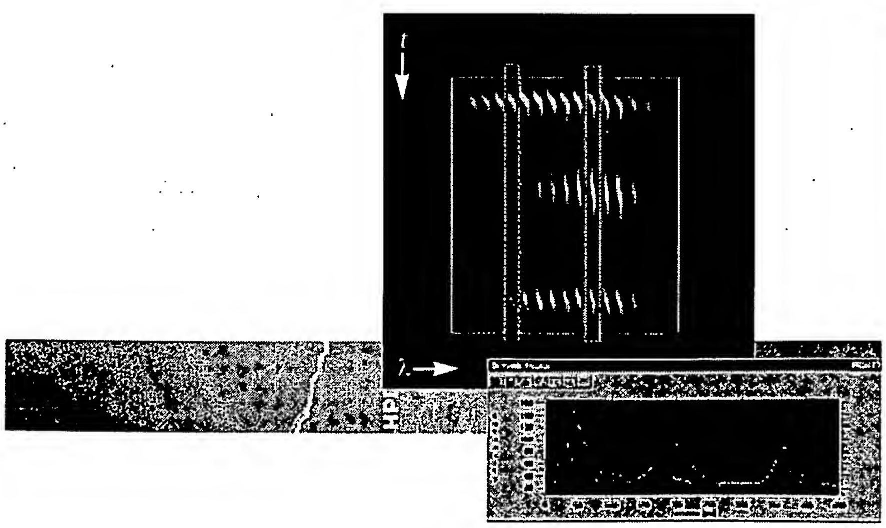
With contrast enhancement

Dim image of a plasma discharge (by courtesy of the Kyushu University)

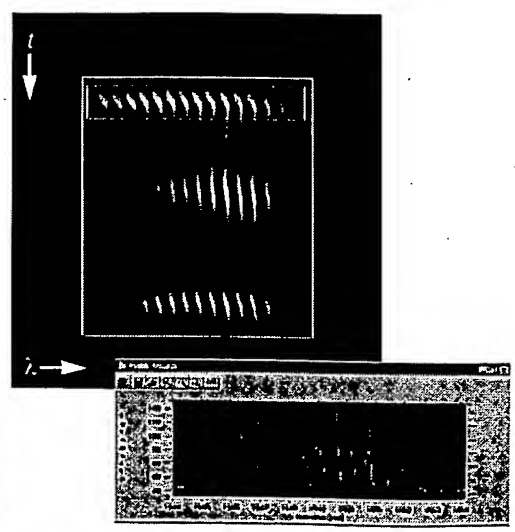
With pseudo colors

Intensity profiles

After acquiring a streak image you will usually want to extract intensity profiles along the time or the other axis. These profiles are created by integration inside of sampling windows which may be oriented either vertically or horizontally.
HPD-TA can handle up to 10 different profiles simultaneously, displayed in different colors. Simple analytical parameters like peak, rise/fall time, FWHM and others can be obtained on the fly. Many options allow convenient operation, like AutoZoom, AutoUpdate, and so on.
The example below shows how two different kinds of results can be extracted from one single streak image. The image is the same as that on page 2 under Live mode, but now it has been frozen in memory.
In the picture on the left, vertical profile windows yield the temporal intensity traces. The red and green trace are the profiles of only one laser diode mode respectively, while the blue trace sums over all wavelengths.
In the picture on the right, the red trace shows the spectrum of the leading pulse only (equivalent to gated spectroscopy with a gate time of only a few ps), while the blue trace sums over the whole time span (equivalent to steady-state spectroscopy).



Time-resolved LD spectrum; extraction of temporal traces at fixed wavelength bands



Time-resolved LD spectrum; extraction of spectra at fixed time positions

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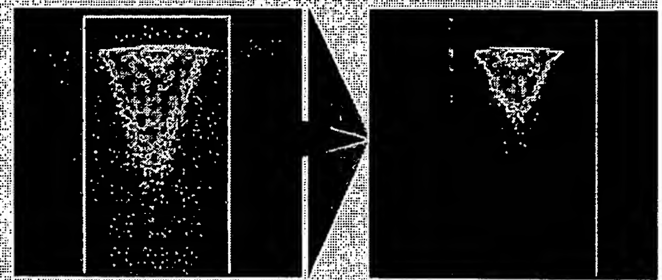
Data correction

HPD-TA offers a full range of data correction and pre-processing functions. These are used to eliminate data artifacts caused by the characteristics of the experimental setup and measuring apparatus.

Background Correction

Background Correction is a subtractive correction eliminating offset signal caused by CCD dark current, video noise or background light such as stray light.

Background Correction is also possible in real-time in Live Mode.

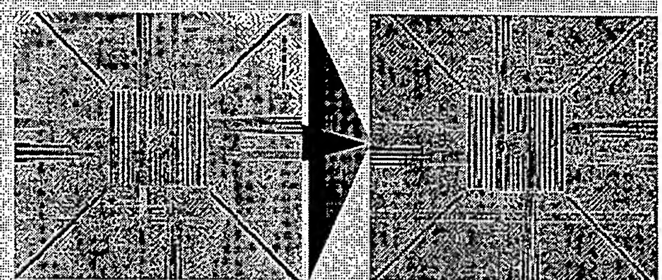


Time-resolved fluorescence spectrum   *After background subtraction*

Shading Correction

Shading Correction is a multiplicative correction compensating for overall system non-uniformities such as those caused by photocathode shading or imperfect optical components in the measurement setup.

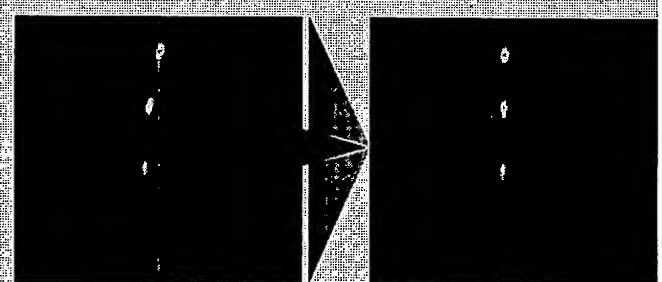
A sub-case is ***Spectral Sensitivity Correction***, which is used in time-resolved spectroscopy and compensates for the wavelength-dependent efficiency of the spectrograph and detector.



TV test pattern   *After shading correction*

Curvature Correction

Curvature Correction performs a geometric image correction. Its main use is in combination with Synchronous Blanking, a special mode of synchroscan operation, which is causing an elliptical distortion of the streak image. Curvature Correction allows you to rectify such images.

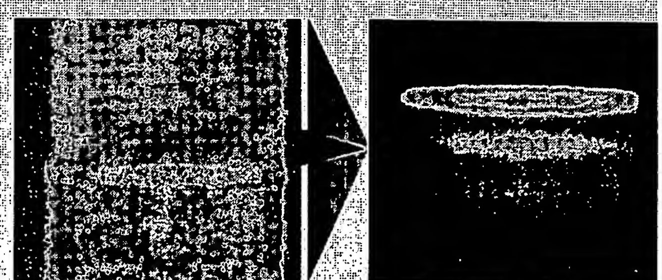


Oscillating laser diode   *After curvature correction*

Jitter Correction

In some cases, especially repetitive single-sweep streak, simple data accumulation does not give satisfying results due to timing jitter between subsequent data records. The Jitter Corrector can automatically determine individual timing shifts for each data record prior to accumulation, thereby eliminating signal broadening.

Jitter Correction is typically used in combination with Sequence data.



Oscillating LD, integration with large jitter   *After jitter correction*

Data calibration

HPD-TA provides a versatile and easy-to-use scheme for attaching calibration information to all measurement data. Both image axes can be calibrated, the time axis and the perpendicular axis (which may be a wavelength axis if the streak camera is used in conjunction with a spectrograph). These calibrations may be linear or nonlinear.

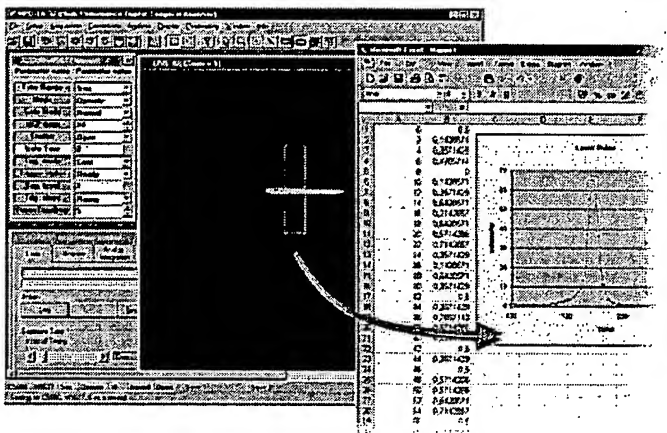
Usually, the time calibration of a streak system is predefined by the factory, but the user can define new calibrations easily whenever he wants.

After setup, all calibration handling by the system is fully automatic and does not require any special attention by the user. For instance, when working with partial or binned images or when extracting profiles from images, calibration information is always automatically recalculated and inherited.

Also, calibration data and other useful information (such as measurement parameters) are automatically embedded in files saved to disk, so there is no need to write down such information manually.

Data export

Frequently, users wish to access measurement data by external programs for special analysis or display purposes. Hamamatsu has been careful to make such tasks as easy as possible. Consequently, HPD-TA supports popular and easy-to-read data formats for images and profiles. All data formats are fully documented in the extensive user manual.



Major data formats:

2-D data (images):

- *HPD-TA binary format (compact, fast)*
- *TIFF format (for presentation, publishing, printing)*
- *ASCII format (for easy import into data analysis programs)*
- *Clipboard and DDE (quick data copying and automated data transfer, for small images only)*

1-D data (profiles):

- *2-column ASCII (time axis, intensity) (easy import into analysis programs, spreadsheets, etc.)*
- *Clipboard and DDE (quick data copying and automated data transfer)*

Example: Automatic data transfer via DDE to Excel

User-defined code

For users who want to combine their own software code with the HPD-TA program, two independent techniques are provided.

User Function

This is a simple way how the user can add his own code, automatically invoked at certain predefined situations. Application examples include adding an own data analysis function - automatically done each time a profile has been updated –, or sending control signals to third-party hardware, synchronized with HPD-TA's Sequence recording.

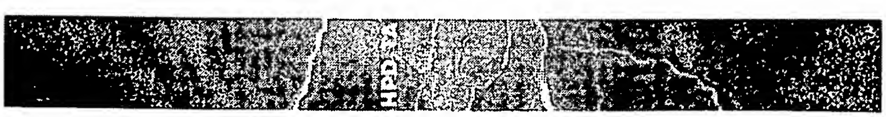
Usage of this feature requires a basic familiarity with C language and a compiler that can produce Windows DLL code. This feature is included in HPD-TA as standard.

Software Developer's Kit

For special purposes, certain customers may wish to develop own software solutions that go beyond what can be realized by the "User Function" feature. Such a case is typically given if an own control logic is required, if the streak system shall be integrated into a larger complicated facility, or if a customized user interface is desired.
For such cases, we offer a developer's kit which allows to bind HPD-TA-specific software components into own developed programs in a powerful and elegant fashion. The technique is based on Microsoft's Component Object Model (COM).

The kit is aimed at serious software developers only. It requires a Windows development tool supporting COM technology.

This kit is optional and is provided on special request only, under special license terms.



Optional application modules

Two application-specific add-on modules for the HPD-TA software are currently available. These are optional and must be purchased separately. They are seamlessly integrated into the HPD-TA and can be used without leaving the main program. They are easy to use due to their convenient user interface.

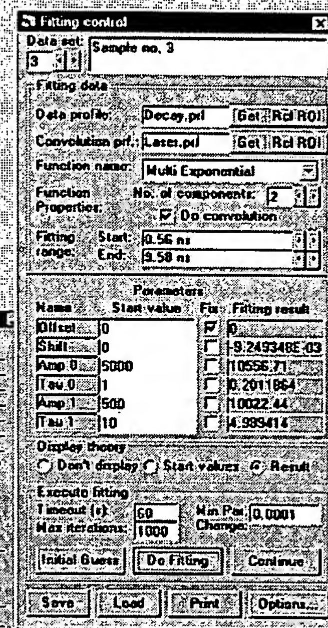
TA-Fit

A tool for quantitative analysis of fluorescence decay emission. TA-Fit enables you to perform quantitative analysis of fluorescence lifetime profiles obtained with the HPD-TA in either analog or photon-counting mode.

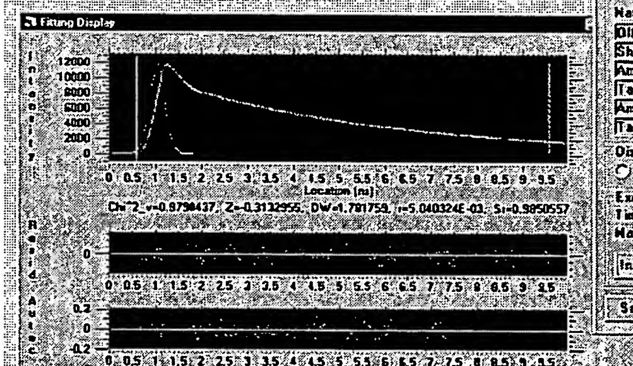
Features:

- Fitting engine with advanced adaptive least-square fitting algorithm
- Deconvolution with excitation pulse
- Determination of multiple lifetime components as well as shift and offset
- All parameters can be either fixed or floating
- Quality of fit result via chi-square, Durbin-Watson, autocorrelation, ...
- Graphical user interface allows easy tweaking of fit parameters and seeing their influence instantaneously
- User-defined stop conditions
- User-defined fitting sets for quick access to previously defined settings

Data fitting is always a job that requires some basic level of understanding and skill. However, TA-Fit is designed in such a way that it allows even non-specialists to obtain reliable results with minimum difficulty. The extensive user manual not only explains the practical usage of the software, but also illuminates the theoretical background and contains a step-by-step tutorial.



Fitting control window



Fitting display window

TA-Absorption

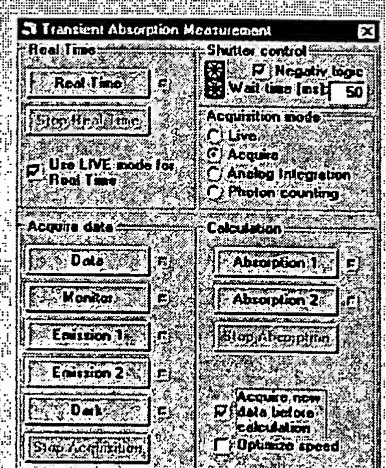
Transient absorption measurements are a well-known, powerful technique in the chemical sciences. Not so well-known yet is the fact that the use of a streak system adds even more power, yielding rapid, multichannel recording of data with superb temporal resolution.

TA-Absorption is a tool that helps you to obtain such transient absorption spectra easily.

By using TA-Absorption, high-performance transient absorption measurements become convenient, safe, and fast.

Features:

- Automatic recording of all needed data (sample, reference, background, fluorescence if present) at once
- Automatic driving of external shutters controlling the beam paths
- Performing the calculations to obtain quantitative absorbance data



Transient absorption control window

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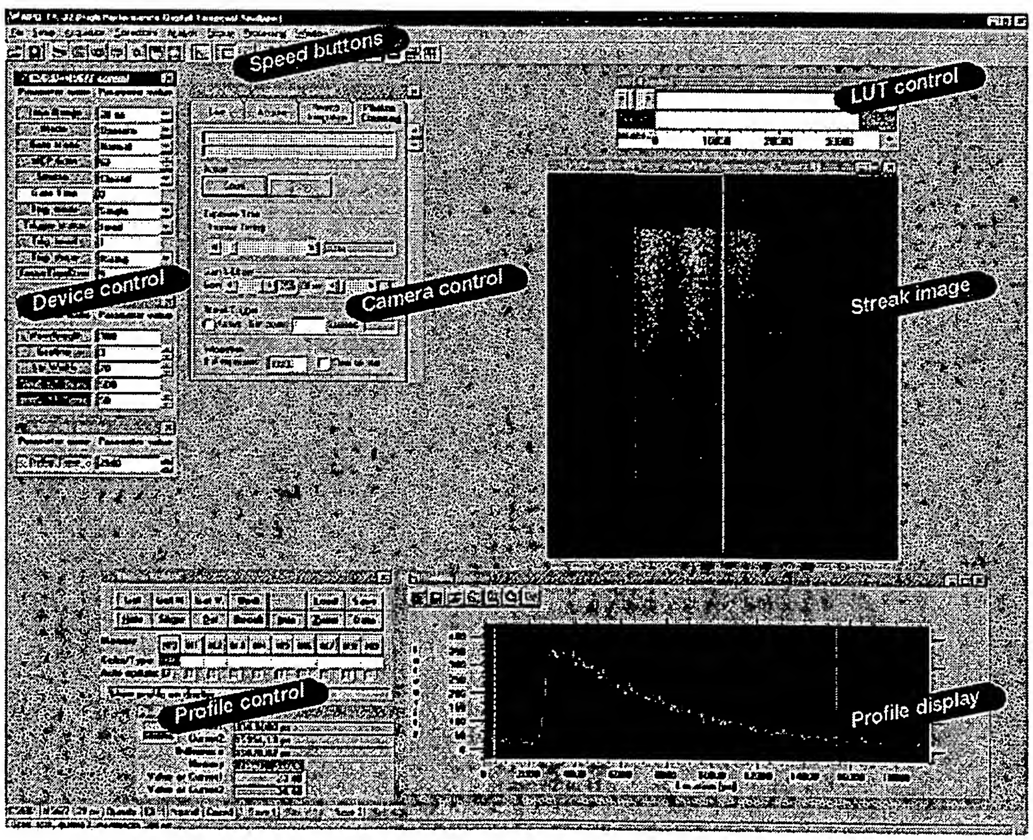
Supported CCD cameras

Items	Dual-Scan Version	ORCA Version	Video Version
Camera type	Dual-Scan Cooled CCD Camera (C4880 series)[*]	Cooled Digital CCD Camera (C4742-95 "ORCA" series)[*]	Video CCD Camera (CCIR or RS-170)
Coupling method	Relay lens	Relay lens	Fiber optics
Resolution	typ. 1000 x 1018 pixels	1280 x 1024 pixels	768 x 493 pixels (CCIR) or 756 x 581 pixels (RS-170)
Frame rate	typ. 0.3 Hz (slow scan) typ. 7 Hz (fast scan)	9 Hz (normal) 18 Hz (superpixel)	25 Hz (CCIR) or 30 Hz (RS-170)
Single exposure time	20 ms to 30 min	100 µs to 10 sec	40 or 33 ms
Analog integration	on chip / into memory	on chip / into memory	into memory
Dynamic range single frame integration	12 or 14 bits 16 bits	10 or 12 bits 16 bits	8 bits 16 bits
Binning mode	●	—	—
Superpixel mode	●	●	—
Subarray scan mode	●	—	—

(*) There are various subtypes available of the C4880 and the ORCA series cameras. The numerical figures given here are typical values and may depend on the exact model.

Typical workspace



HAMAMATSU www.hamamatsu.com

Hamamatsu Photonics Deutschland GmbH
Arzbergerstrasse 10, D-82211 Herrsching, Germany, Phone: (49)8152-375-0, Fax: (49)8152-375-222, email: info@hamamatsu.de

Japan:	Hamamatsu Photonics K.K., Systems Division: 812 Joko-cho, Hamamatsu City, 431-31, Japan, Phone: (81)053-431-0124, Fax: (81)053-435-1574
USA and Canada:	Hamamatsu Photonics Systems: 360 Foothill Road, Bridgewater, N.J. 08807, U.S.A., Phone: (1)908-231-1116, Fax: (1)908-231-0852
France:	Hamamatsu Photonics France S.A.R.L.: 8 Rue du Saule Trapu, Parc du Moulin de Massy, 91300 Massy, France, Phone: (33)169 53 71 00, Fax: (33)169 53 71 10
United Kingdom:	Hamamatsu Photonics UK Limited: Lough Point, 2 Gladbeck Way, Windmill Hill, Enfield, Middlesex EN2 7JA, United Kingdom, Phone: (44)208-367-3560, Fax: (44)208-367-6384
North Europe:	Hamamatsu Photonics Norden AB: Smidesvägen 12, SE-17141 Solna, Sweden, Phone: (46)8-50 90 31 00, Fax: (46)8-50 90 31 01

Streak camera operating in the mid infrared

Marcel Drabbels* and L. D. Noordam

Stichting voor Fundamenteel Onderzoek der Materie, Institute for Atomic and Molecular Physics, Kruislaan 407, 1098 SJ Amsterdam, The Netherlands

Received May 13, 1997

An atomic streak camera has been constructed that operates from the near to the far infrared. The photocathode used in conventional streak cameras for the conversion of photons to electrons has been replaced by gas-phase atoms in a Rydberg state. The low binding energy of the electron in a Rydberg atom combined with the large photoionization cross section of a Rydberg atom makes Rydberg atoms suitable for use in an infrared streak camera. Operation of the streak camera is demonstrated at 2.6 μm, well beyond the spectral range of any conventional streak camera.

EXHIBIT D

Abstract— An atomic infrared (IR) streak camera is demonstrated that operates in the mid- and far-infrared ($\lambda = 5–85\ \mu m$), well beyond the long wavelength cutoff of conventional streak cameras. The temporal and spectral characteristics of the streak camera are determined using the FELIX free-electron laser as the IR light source. The temporal resolution of the streak camera was found to be as short as 1.2 ps. The high sensitivity of the streak camera is demonstrated by single-shot characterization of the IR pulses of FELIX.

Index Terms— Free-electron laser, infrared detector, streak camera, ultrafast electronics, ultrafast optics.

What is a Streak Camera? EXHIBIT E

[What is a Streak Camera?]

Although we call it a "camera", a streak camera is quite different from the video cameras and still cameras that we load with film to take pictures of the people and objects around us.

The streak camera is a device to measure ultra-fast light phenomena and delivers intensity vs. time vs. position (or wavelength) information. It's name dates back to the early days of the high speed rotating drum cameras. These cameras would "streak" reflected light onto film. No other instruments which directly detect ultra-fast light phenomena have better temporal resolution than the streak camera.

Since the streak camera is a two dimensional device, it can be used to detect several tens of different light channels simultaneously. For example, used in combination with a spectroscope, time variation of the incident light intensity with respect to wavelength can be measured (time-resolved spectroscopy). Used in combination with proper optics, it is possible to measure time variation of the incident light with respect to position (time and space-resolved measurement).

[Features]

• Simultaneous measurement of light intensity on both the temporal and spatial axis (wavelength axis)

By positioning a multi-channel spectroscope in front of the slit (for the incident light) of the streak camera, the spatial axis is reckoned for the wavelength axis. This enables changes in the light intensity on the various wavelengths to be measured (time-resolved spectroscopy).

• Superb temporal resolution of less than 0.2 ps

The streak camera boasts a superb maximum temporal resolution of 0.2 ps. This value of 0.2 ps corresponds to the time it takes for light to advance a mere 0.06 mm.

• Handles anything from single event phenomena to high-repetition phenomena in the GHz range

A wide range of phenomena can be measured simply by replacing the modular sweep unit.

• Measurement ranges from X-rays to the near infrared rays

A streak tube (detector) can be selected to match any wavelength range from X-rays to near infrared rays.

• Ultra-high sensitivity (single photoelectron can be detected)

The streak tube converts light into electrons, and then multiply it electrically. By this, it can measure faint light phenomena not to be seen by the human eyes. This enables monitoring of extremely faint light; even single photoelectron can be detected.

• Dedicated readout system

A dedicated readout system is available which allows images recorded by a streak camera (streak images) to be displayed on video monitor and analyzed in real time. This enables the data to be analyzed immediately without the delay of film processing.

[Operating Principle]

Fig. 1 shows the operating principle of the streak camera. The light being measured passes through a slit and is formed by the optics into a slit image on the photocathode of the streak tube. At this point, four optical pulses which vary slightly in terms of both time and space, and which have different optical intensities, are input through the slit and arrive at the photocathode.

The incident light on the photocathode is converted into a number of electrons proportional to the intensity of the light, so that these four optical pulses are converted sequentially into electrons. They then pass through a pair of accelerating electrodes, where they are accelerated and bombarded against a phosphor screen.

As the electrons produced from the four optical pulses pass between a pair of sweep electrodes, high voltage is applied to the sweep electrodes at a timing synchronized to the incident light (see Fig. 2). This initiates a high-speed sweep (the electrons are swept from top to bottom). During the high-speed sweep, the electrons, which arrive at slightly different times, are deflected in slightly different angles in the vertical direction, and enter the MCP (micro-channel plate).

As the electrons pass the MCP, they are multiplied several thousands of times, after which they impact against the phosphor screen, where they are converted again into light.

On the phosphor screen, the phosphor image corresponding to the optical pulse which was the earliest to arrive is placed in the uppermost position, with the other images being arranged in sequential order from top to bottom; in other words, the vertical direction on the phosphor screen serves as the time axis. Also, the brightness of the various phosphor images is proportional to the intensity of the respective incident optical pulses. The position in the horizontal direction of the phosphor image corresponds to the horizontal location of the incident light.

In this way, the streak camera can be used to convert changes in the temporal and spatial light intensity of the light being measured into an image showing the brightness distribution on the phosphor screen. We can thus find the optical intensity from the phosphor image, and the time and incident light position from the location of the phosphor image.

X-Ray Streak/MultiFrame Camera K002

K002 camera built aroud Streak/Framing tube with MCP photocathode and 40 mm Image Intensifier. This type of Phocathode covers wide spectral range from X-ray to UV (1 MeV - 10 eV). Camera can operate in either Streak or MultiFrame mode. Temporal resolution is 200 ps in streak mode. Exposure times cover range from 5 ns to 100 ns with selectable number of frames 4, 6, or 8.

Photocathode	MCP
Photocathode size	12mm Dia
Spatial resolution	10 lp/mm
Temporal resolution	200 ps
Streak speeds range	25 ps/mm - 2.5 ns/mm
Jitter	± 50 ps
Exposure time	5 ns - 100 ns
Repetition rate	up to 10 Hz
Dimensions	91 x 21 x 40 cm
Weight	37 kg

EXHIBIT F

ATTACHMENT 1(e)

EXPLANATIONS OF RELEVANCY OF REFERENCES	ATTORNEY DOCKET NO. 1071.1044DC	APPLICATION NO. 10/674,476
	FIRST NAMED INVENTOR Takatoshi HIROTA, et al.	
	FILING DATE October 1, 2003	GROUP ART UNIT 2879

Prior art statement

(1) "Printed Publication" as Prior Art

Asia Display `95 is a "Printed Publication".

Asia Display `95 meeting of SID (Society for Information Display) was opened in October 16-18th, 1995 as written at the cover.

A paper of "Luminance Observed above the Anode Electrode in Co-Planner Structure ACPDP" was announced in public in the meeting on October 18, 1995 as written in the paper.

On the other hand, the present invention was filed in the U.S on June 3, 1997 and the priority date which is Japanese filing date is June 12, 1996. Accordingly, an art described in the paper is a prior at of the present invention,

(2) Prior art disclosed in the paper

The paper explains a result of an experiment regarding a reflecting type, surface discharge, color AC - PDP.

Though it is not explicitly shown, it is supposed that the PDP is a general type, three electrode structure.

It is written in the paper that enclosed discharge gas is a mixture gas of Ne and Xe and a mixture ratio of Xe in the mixture gas is 5 %.

Each spectrum of light emitted from the PDP is observed by the experiment.

That is, phosphor light is shown in Fig. 2 (1), Ne orange light is shown in Fig. 2 (2) and Xe infrared light is shown in Fig. 2 (3).

A presence of infrared light emitted from Xe gas is recognized in the experiment.

And a IR-cut filter is used for removing an unnecessary light in observing a luminescence of phosphor light as shown in Fig. 2 (1).

Accordingly, a state for cutting infrared light emitted from PDP is made in the experiment.

(3) A difference between the present invention and the prior art is disclosed in the paper However, it only discloses that an IR-cut filter is used for removing an unnecessary light in observing a luminescence of phosphor light as shown in Fig. 2 (1)

And it only discloses that infrared light emitted from 5% Xe gas is observed as shown in Fig. 2 (3).

However, it does not disclose or suggest a problem caused by infrared light, such as malfunction of near infrared remote control for domestic electric appliances in the home. Accordingly it does not disclose at all a necessity of a cut filter of near infrared.

Needless to say, it does not disclose a concrete structure of PDP for cutting near infrared, such as a protection plate and a construction of a casing as in claim 6 and a protection plate at a predetermined distance from a display panel as in claim 16.

(4) Distinction

As explained in the above, though a IR-cut filter is used for spectrum observation in the paper, it is not understood to constitute a necessity of an IR-cut filter in a PDP product.

IR-cut filter is only used for observing a luminescence of. phosphor light in the paper.

And it is not recognized to be a problem caused by infrared light, such as malfunction of near infrared remote control for domestic electric appliances in the home, and a necessity for solving of the problem by removing near, infrared emitted from Xe gas.

As such, the present invention is not obvious, based on prior art in the paper.